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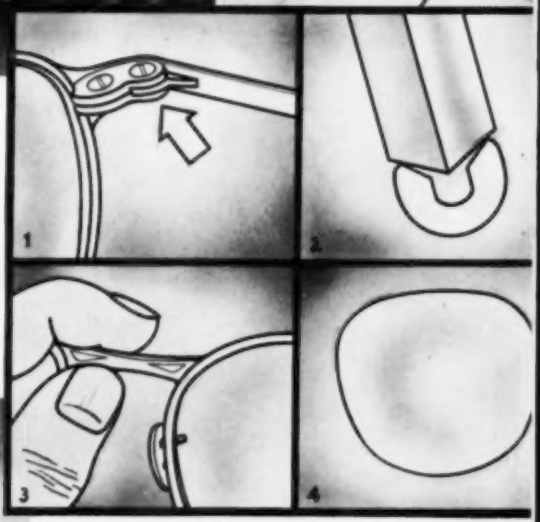

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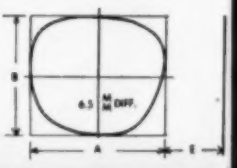

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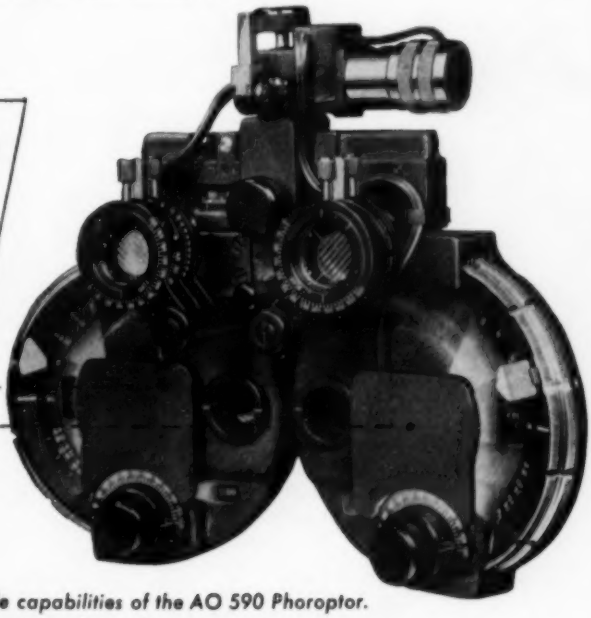

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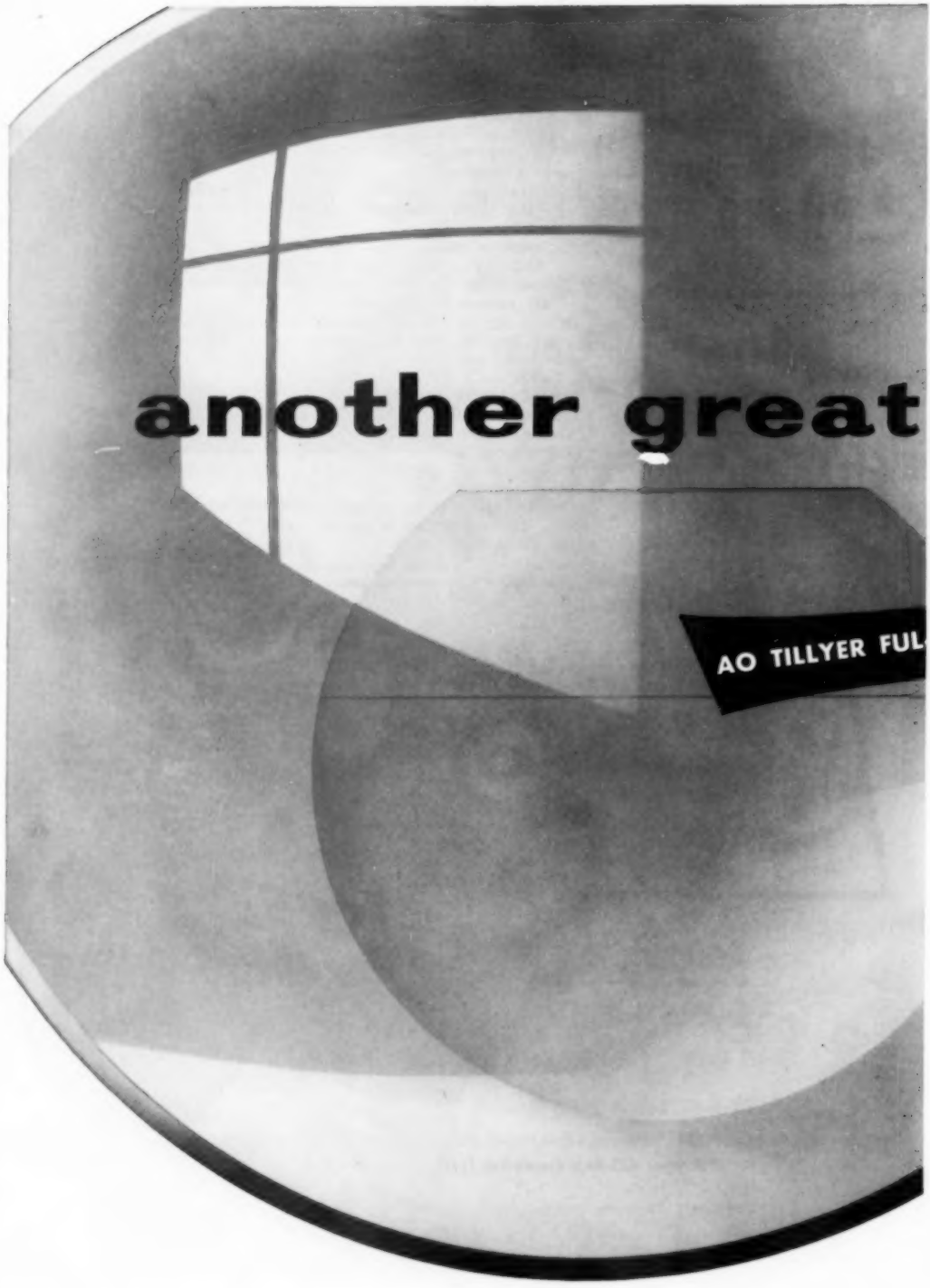
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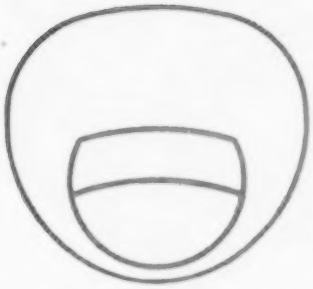

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THE FILLING-IN PROCESS*

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It was in 1668 that Mariotte described how to demonstrate the blindness of the head of the optic nerve: by fixating to one side of an object in monocular vision, one can make the object disappear. This bit of scientific magic promptly became known to Charles II, who enjoyed "beheading" his courtiers with it. Eventually of course the physiological blind spot received a proper anatimico-physiological explanation. But there remained something about it, mysterious enough for Sir David Brewster to include the phenomenon in his "Letters on Natural Magic" (1832).

The queerest thing about the blind spot was never better set forth than by Brewster. He said: "We should expect, whether we use one or both eyes, to see a black or a dark spot upon every landscape, within 15° of the point which most particularly attracts our notice. The Divine Artificer, however, has not left his work thus imperfect. Though the base of the optic nerve is insensible to light that falls directly upon it, yet it has been made susceptible of receiving luminous impressions from the parts which surround it, and . . . the spot . . . in place of being black, has always the same color as the ground." "When both eyes are open, the object whose image falls upon the insensible spot of the one eye is seen by the other, so that it is not invisible, yet it will only be half as luminous, and therefore two dark spots ought to be seen."

Modern authors, in explaining why the blind spots are not continuously visible as ovoid shadows on a blank wall, are content to say that the area imaged on one nerve head is simultaneously imaged upon functional retina in the other eye, and so is seen after all. That was not enough for Brewster. He assumed that what we nowadays call "binocular summation of brightness" does occur. The nerve head in one eye and the binocularly correspondent retinal area in the other

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eye would receive, between them, only half as much effective stimulation from a homogeneous wall as any other pair of similar correspondent retinal areas. To Brewster's mind, it remained paradoxical that blind-spot areas of a—say—100 millilambert wall do not appear like shadows of only 50 millilambert luminance.

The reason, of course, is that each blind-spot area would appear, even in monocular vision, to have a luminance of 100 millilamberts, not zero millilamberts. It is "filled in" by whatever visual material immediately surrounds it in the field. Moreover, it is not only the surrounding brightness that appears within the blind-spot area, but also the color, and even the pattern. Monocularly, a white wall shows no black or gray spot on it. But a pink wall is homogeneously pink, a green wall solid green. A checkerboard has no patch lacking "squares," and a printed page has "words" also in the neighborhood of 15° temporal from the fixation point!

At one time, I tried to keep a file of all the explanations ever offered for this subjective filling-in of Mariotte's Spot. I finally gave up hope of ever making the list complete—there have been so many. And, several of the hypotheses seem perfectly adequate individually and yet cannot be reconciled with each other. This is only natural, since each explanation is strictly an *ad hoc* one to begin with.

It is not generally recognized that the optic-nerve head is not the only spot that is blind "physiologically," i.e., normally. Another sharply defined retinal spot is also blind, in weak illuminations, in nearly all of us. This is the little area at the center of the fovea which is normally devoid of rod visual cells. The physiological night-blindness of this locus was probably known to the Phoenician sailors who first navigated by the stars. Its first scientific attention, however, came from Arago in 1858. We may, then, speak of "Arago's Spot," and compare it with Mariotte's Spot. The comparison is perfect. When an observer views a sheet of white paper illuminated below the cone threshold, he sees no black or gray spot where he is looking. The whiteness and brightness of the paper are homogeneous and continuous right to the fixation point, although if the latter is a black dot, it is invisible. Arago's spot is "filled in" just as perfectly as is Mariotte's. The theorists who have explained the nerve-head filling-in have not known this, or several of them should have been embarrassed; for, most of the *ad hoc* hypotheses for Mariotte's spot simply cannot be carried over to Arago's.

Arago's spot—usually taken to subtend 2°—contains within itself a still smaller spot which is subject to a *chromatic* filling-in process. I

refer to the ½° foveocentral area which is ordinarily devoid of receptors for blue. While ½° may sound small, small enough for any peculiarity to escape notice, be it remembered that ½° is about the subtense of the full moon—a very noticeable object. It is easy to demonstrate that a blue dot, imaged within this blue-blind area in the fovea, loses its subjective blueness. But on a sheet of blue paper there is seen no ½° hole, or white or gray spot, or black spot. The paper is blue all over.

Such scotomata as Mariotte's, Arago's, and that for blue would be called *negative*, by which is meant that they are not continuously evident to the subject but are demonstrable only by the disappearance of something imaged within them. They are set off sharply from *positive* scotomata such as may be caused by a foreign body lodged in the vitreous close to the retina, on which it casts a dense shadow. A positive scotoma, by definition, is an area in the visual field which appears black or dim and is *not* filled in with whatever surrounds it.

Negative scotomata are by no means confined to normal visual systems. In fact, the terms "positive" and "negative," in this connection, were adopted by neurologists to facilitate the description of the symptoms given by lesions of the visual apparatus. Local destruction within the primary visual area of the cortex (Area 17)—as by a bullet wound—produces blindness within perfectly congruous corresponding areas in the monocular visual fields, hence a binocular scotoma. This is negative, i.e., the patient is unaware of it unless he notes the disappearance of an object in that part of his visual field. Ordinarily, a cortical-lesion scotoma is kept filled in, in exactly the manner of the physiological scotomata.

The characteristic scotoma of the early portion of the visual migraine aura is in a sense intermediate between the physiological and the pathological. The lucky majority never have it; but, the "lesion" that causes it is not structural nor permanent. Because of its cortical origin, it is negative. The migraine victim may suspect that it has appeared. A peculiar malaise prompts him to look for it. The point is, he does have to search for it, by fixating here and there around some landmark until the latter vanishes. Only when it has become quite large does the migraine scotoma become self-evident: the filled-in contents of the area seem spurious; and, the area is always neatly surrounded and sharply delineated by the slowly dilating fortification spectrum. Then, too, as the scotoma enlarges it ordinarily soon ceases to be "absolute," and objects come to be seen in the area as if through a haze.

Even if the optic radiation on one side should be completely

severed, producing a diagrammatic homonymous hemianopia, the patient would apparently have to *learn* that he had a blind area. The newly hemianopic individual is said to be unaware that he cannot see to one side until he has had many collisions with unseen things. The apogee of this unawareness is reached in Anton's disease. Paradoxically, this is a *psychiatric* affection of a mentally "normal" person. He is completely blind, but does not know it and cannot be convinced of it. This is the amazing result of the bilateral destruction of either the visuosensory cortex or the optic radiations, with preservation of the visual association areas. The patient's visual field is full of things, which he can describe minutely. The only catch is that none of the things is really there at all.

The hypothesis I am working up to in this paper involves an assumption that the filling-in phenomena relating to all negative scotomata—physiological, migrainous, and truly pathological—have a great deal in common and are based upon a single cerebral process. If an inclusive theory can displace half a dozen separate *ad hoc* explanations, this should seem like progress.

Let us assume that negative scotomata *are* all filled in by one and the same mechanism, and let us take a biologist's point of view and ask ourselves what adaptive value this mechanism can have, if *all* it does is fill in scotomata. In plain talk the question is, is it a good thing if we have such a (special!) mechanism? The answer has to be *no*.

Consider the predicament of a mammal who is not a primate nor a carnivore, but has his eyes well at the sides of his head, like a rabbit. Whatever is imaged upon one optic nerve can *not* be seen by the other eye. If the filling-in process is an ancient one, and rabbits have it as well as humans, then the rabbit does not know that there is a great cone of space to either side, within which an enemy can walk up to him unseen. Biologically, this is certainly not a good thing. Far better that the rabbit's nerve-head scotoma should be positive so that the rabbit could never forget to check on the field-content there, by making some small movement of eye or head.

On the other hand, if filling-in is a peculiarly primate phenomenon, what is the point of it, considering that we do see with one eye whatever is on Mariotte's spot in the other? It seems unnecessary for any of the physiological scotomata to be negative. That they all are, must mean that they are filled in by a process that has other values for our vision. This is irrespective of whether our non-binocular ancestors had that process or not (though I am sure they did have it).

Furthermore, is it desirable to be unaware that we have a lesion

in the upper reaches of the central visual system? Ask any migraine victim, whose visual aura has ever descended upon him while he was driving an automobile. Is it a good thing, or in any way necessary, for an organism *not* to know that its brain has been damaged? The situation seems in striking contrast with other results of brain injury. Such injury is entirely painless. The biologist explains pain as an adaptive device for causing a sick or injured animal to become quiescent, which is the best thing it can do if it is to get well. The brain, however, never hurts. A wild animal whose brain has been torn has a fractured skull and hasn't a chance of getting well. Why *should* the brain hurt in order to immobilize him? Again, injured parts generally heal, through regeneration or the formation of scar tissue. But the brain and spinal cord are conspicuous for being unable to repair themselves if damaged. Teleologically, there is no point to a capacity for regeneration here, for a brain-injured wild animal would not live long enough to heal the injury.

In these other respects, Nature seems to have surrendered in advance of any brain lesion, as if she expected any such lesion to mean a fractured skull and early death from meningitis (or sooner). It therefore seems silly to suppose that the negativity of brain-lesion scotomata is due to any special arrangement. Like that of the retinal physiological scotomata with which it is perfectly identical, it must result from a filling-in process with which we are endowed because we cannot get along without it—a process which goes to work to fill in any scotoma not due to a black shadow on the retina, and cannot help but do this, but which exists for some other purpose, some purpose in *normal* vision with *functional* retinal areas. We proceed, then, to consider what this underlying filling-in process must be for and what it may be like.

We start in a strange place—an automobile. When we switch on the headlamps, the wires leading to them carry a continuous current. The lamps light, and stay lit until we switch them off. We are not surprised. The sparking of the spark plugs is however not continuous, although the ignition switch is turned on and left on. We note, however, that the distributor is opening and closing the circuit to each plug. So, we are not surprised at discontinuity in the presence of continuity in the same system.

The visual system, on the other hand, harbors a tremendous surprise for us. When the retina is under continuous illumination of a certain strength and we are enjoying a continuous sensation of a certain brightness and chromaticness, the optic nerve is not carrying a continuous message of corresponding strength and kind at all. Nothing much

happens in the optic-nerve fibers unless the stimulation of the connected receptors is *changed*—turned on, turned off, increased suddenly and considerably, or decreased suddenly and considerably. The wiring between the retina and the visual cortex and the cortex itself, an electrical engineer would say, responds not to the stimulus intensity but to the derivative of the intensity. Yet, the sensation of light appears to be continuous when the light itself is physically continuous (and sometimes even when it is not).

The work of Granit, over a period of many years, has thoroughly established that in the optic nerve of any mammal (rat, cat, or man) there are only certain physiological types of fibers, as identified by amplified electrical activity picked up from them with microelectrodes.

There are fibers which exhibit a brief burst of "spikes" (single nerve-impulses) shortly after an illumination is thrown *on* the retina. There are others which show such a burst only after the illumination is shut *off*. Still others manifest both an "on" and an "off" effect. The types, naturally enough, are called on-fibers, off-fibers, and on-off fibers. Some fibers may seem to change type if the adaptation-state of the retina is greatly changed. This is because on-effects in both on-fibers and on-off fibers are initiated almost entirely by the activity of the dim-light visual cells, the rods—whereas off-effects in off-fibers and on-off fibers stem from the bright-light receptors, the cones.

Not all fibers are completely silent between "on" and "off." Many conduct in a desultory fashion while the steady illumination is bathing the retina. But the total number of such impulses is small, and does not bear the mathematical relationship to stimulus intensity and strength of sensation that is seen in the compact bursts at "on" and "off." It is not considered that this low-grade continuous activity can possibly be the correlate of the continuously high brightness of a steady light, or the correlate of its continuous coloredness either. The brightness is related to the high b-wave of the electroretinogram and to the on-effects, which, so to say, represent b-wave potential parcelled out to serve as stimulation to individual ganglion cells. It has been claimed that all information about color is transmitted only in off-bursts, which have been shown to be analyzable into three subgroups of impulses separated in time (Donner, 1950).

When (as in Granit's work) the whole retina of an animal is flooded with light, and any fiber under the microelectrode proceeds to "fire" only at either "on" or "off" or at both, it may seem that we should never see a continuous light *as* a continuous light. Yet, we do—we do not merely see a bright flash when the light comes on and another when it goes off (with perhaps a dim glow in between).

An illumination which is confined to a spot, like the retinal image of a lamp, has no special magic. The optic-nerve fibers conducting away from that retinal spot do not now behave any differently from what they did when the whole retina was illuminated. Each is still either an on- or off-fiber or else an on-off fiber. But something special does go on at the margin of the spot. Here, a multiplicity of micro-electrodes would show a perfect scintillation of on- and off-effects tumbling after one another in the fibers related to the ring of receptors around the spot.

This margin-activity is brought about by a phenomenon which, for long after its discovery, was thought of as a defect in the operation of the visual apparatus. When one tries to fixate a point steadily, and thinks one is doing so, the eyeball is actually in an almost continuous state of vibration. In the horizontal plane this fine, fast, so-called physiological nystagmus has a frequency which fluctuates from 30 to 90 per second (averaging about 50), and an amplitude of something less than a minute of arc, according to the latest figures (Higgins and Stultz, 1953).

Although this "error" or "flutter" of fixation went unappreciated for a long time,* it was eventually worked into the theories of Weymouth (1923) (see Walls, 1943) and of Marshall and Talbot (1942), as something *essential* to any explanation of why vernier visual acuity and stereoscopic visual acuity are so amazingly good as they are. These theories have never been properly tested, and it is still an open question whether the physiological nystagmus is generally helpful or perhaps detrimental to these and some other kinds of discrimination, such as simple resolution. But the consensus, today, is that the physiological nystagmus exists because it is useful to vision. Even if, basically, it is due to an almost inevitable tremor of extra-ocular muscles which might be difficult for the system to damp out if it had to try to do it, we should still have to say that if—like God—the physiological nystagmus did not exist, it would have had to be invented.

This is not to say that anyone, to my knowledge, has ever said that the physiological nystagmus is indispensable for vision—only that it is a good thing,** and not a defect, or is a defect that has turned out to be a good thing (like Panum's areas, which neuron systems could never have made to have a diameter of zero even if that were desirable).

*It was first noticed in the pioneering eye-movement photographs of Raymond Dodge.

**The very latest pronouncement I can find says no more than that "It seems quite probable . . . that involuntary eye motion makes a significant contribution to the perception of fine detail" (Higgins and Stultz, 1953).

My hypothesis of the filling-in of negative scotomata does, however, require me to say that if it were not for the physiological nystagmus *we would not see at all*. Whenever our eyes moved, we would detect a blur, no more; and when they came to rest with anything imaged steadily on the retina, that object would disappear too fast for its nature to be noted.

Even allowing the physiological nystagmus, we should see only the contours of objects, by way of receptors which were now within the image and now outside it and sending up now on-effects and now off-effects. That is, contours are all that we would see unless we are provided with a general and never-failing filling-in process, which is always ready to work whether we have any sort of scotoma or not.

If this process always causes us to see, filling the area within any contour, whatever kind of visual material is just at the contour, then it will permit us to see the whole area of any homogeneous stimulus and not merely its perimeter. Optic-nerve fibers "opposite" the whole center of a uniformly lighted area may indeed be completely silent all the time it is lighted. But those relating to the edge of the area will be busy, establishing the brightness and color that are to exist there. Our filling-in process proceeds to use those established quantities and qualities to paint in the area inside the contour. There is nothing to stop this centripetal filling-in—unless the process encounters some new internal contour. There, the whole story will begin again. Of course the slightest imperfections of texture—if they are visible—constitute such interruptions. In fact we should say that it is because they are effective interruptions that they are visible.* So it is that the existence of the filling-in process I am proposing is not negated by the fact that a piece of even the best white paper is far from uniform in appearance—as it would be if "the little man" who fills-in within contours looked only at the edge of the paper and then did his painting with his eyes closed to all internal details.

It will of course be asked, where does this basic and indispensable filling-in process operate? And, how? I have no dogmatic answer for either question. One tends to suppose that any such process must be "cortical." But the primary visual receiving area of the cortex, Area 17, does not seem equipped to perform it. It is by no means certain that the colors of things are put into their images in Area 17. Nothing that we know about the functions of Area 17 suggests that that area

*Notoriously, smooth gradients of intensity, etc. on visual surfaces are not perceived unless they are quite "steep." Such an imperceptible gradient is at once made evident by drawing a black stripe across it. The scanning of a *steep* gradient by the physiological nystagmus generates hosts of on- and off-effects, however, about as if stimulation were being turned completely off and on.

"has any imagination"—it acts more like a dumb secretary, faithfully taking down all the information sent up by the retina but turning this over to other agencies that can put meaning into it. The migraine scotoma has one baffling feature. Although it invariably starts to one side of fixation it can, as it enlarges, bulge across the vertical midline of the field. With this behavior, the migraine scotoma cannot possibly have its genesis in Area 17, which in each hemisphere relates strictly to one half-field only. The process that fills in the migraine scotoma must therefore, it would seem, reside above Area 17.* As for the "how," my ideas are still most vague, and the only suggestion I can make to those who want to try to think the matter through is that perhaps the mechanism of filling-in is closely related to whatever mechanism underlies "stimulus equivalence."

I am not even sure that I am not confusing two kinds of filling-in. Many experimenters have shown in many ways that the apparatus of normal visual perception stands ready to complete any familiar figure when only a few parts of it actually exist objectively in the stimulus-configuration—so long as the latter is not so spare or so sharply seen that nothing (or too much) is "left to the imagination." It is certainly also on this sort of basis that a hemianope, fixating the center of a circle, reports it *as* an intact circle although he can be physiologically registering only a semicircle. The hallucinations of Anton's disease are not only too elaborate to reside in Area 17, but much too intricate to have their whole basis in the process that makes a white disc look white all over.

The relatively simple process I have in mind, which forms a team with the physiological nystagmus to keep us from seeing *only* contours, must find its limitations somewhere between the word-like impressions occupying a Mariotte's area aimed at a newspaper, and the kind of things the Antonite thinks are before him. The process is essentially physiological and not "psychological," in that it is certainly native equipment and can be completely depended upon to be regular and certain in operation. It is, I think, a great error to compare (as some do) the filling in of a negative scotoma with the failure to notice a wrong letter which occurs as the "proofreader's illusion."

*"Above" in the sense of the physiological time-sequence of the stages in the process of vision, that is. The filling-in process may operate in an area topographically "beside" 17 (e.g. Area 19), or may lie at an anatomical level "below" the cortex (e.g. the thalamus or hypothalamus). The filling in of a white spot fixated centrally in monocular vision would have to involve the coöperation of both hemispheres (as does the very perception of an intact spot in spite of the vertical "decussation line" in the retina). But, the two Areas 17 are not known to be directly interconnected and, in fact, can probably be said to be known *not* to be.

The whole idea of a general and physiological filling-in process, such as I have outlined here, is too new* for there to be much experimental evidence bearing upon it. Naturally, there have been no experiments especially designed to test it. I feel safe in assuming that the hypothesis will find enough energetic skeptics so that ingenious experiments will soon occur to more fertile minds than mine. I can, however, point to a few phenomena that speak for the idea and at least one that may seem against it:

There is at least one situation in which one can, so to say, watch the filling-in occur. I refer to the fact that the physiological blind spot of Mariotte can be made to be temporarily visible, entoptically. If one faces a sheet of diffusing glass which is dimly transilluminated and bears a fixation dot, covers both eyes for a few moments, and then uncovers one of them, one may see the blind spot "projected" on the glass. Success depends upon the correctness of aim of the eye at the fixation point before the eye is uncovered, and upon steady holding of the fixation afterward. The appearance may then last for many seconds; but the slightest eye-movement allows the filling-in to take place—"instantaneously," as nearly as one can tell.

In my own case, the entoptic project is a vertically ovoid shadow, about right in angular size and in eccentricity from fixation; but not all see it thus. One of my friends sees such a shadow but it has a *bright* center. For another there is only a small round shadow, and still another sees a diagonal stripe which is tilted one way for one eye and the opposite way for the other. No one reports the project to be black; so, perhaps even when the blind spot is thus visible it is *partly* filled in intensitively (making it a "partial" scotoma) or spatially (where it departs from the expected ovoid form).

The filling-in I propose for homogeneous images falling upon functional retinal areas in normal persons should, if it occurs, cause the intensity threshold for the whole spot to be the same as that for the edge of the spot. Just such a situation was found years ago, by Hecht, Haig, and Wald (1935). They suspected that the reason why the threshold for a big spot is smaller than that for a small one is not that the larger area has a lower threshold because of summation, but that its rim is being imaged farther from the fovea, in a retinal zone

*Those of my hearers who remember the hypothesis offered a decade ago by Fleischer (1943) may question this. As my ideas were developing, I recalled Fleischer's paper and located an abstract of it in my files. I was relieved to find that my own hypothesis actually bears no resemblance to Fleischer's "Theorie der Grenzlinienerregungen." Fleischer does, however, have to be credited with having been the first to assert (on any grounds) that the inner part of a uniform retinal image produces no excitation higher in the system.

whose sensitivity is greater. They did find—for example—that there was no difference in the threshold intensities of a solid light-spot 20° in diameter and a ring of 1° spots 20° in diameter. Hecht, Haig, and Wald left unexplained the fact that the 20° spot was seen as a spot and not as a ring. That, of course, is where the filling-in process comes in.

A perfectly analogous equivalence of a large spot centrally fixated, and a tiny spot eccentric to the extent of the radius of the large spot, was found by Granit and Creed (1928). What they measured was the time lag of the first negative after-image. Since this is not a perceptual aspect of either the inducing spot or the after-image, the *physiological* character of the filling-in process is emphasized. For, Granit and Creed found that while the latency changed when the radius was changed, it was the same for both spots at a given radius—as the filling-in hypothesis would predict.

If the physiological nystagmus is essential for the registration of the margin of an image (with the filling-in process going on—or in—from there), then any constructive elimination of the nystagmus should cause not only the margin of a spot, but the whole of it, to vanish. Riggs and his students have shown that this is just what happens (Riggs and Ratliff, 1952; Riggs, Ratliff, Cornsweet and Cornsweet, 1953). By immobilizing the retinal image through an optical trick, they found that steadily fixated targets disappeared. This demonstrates well enough the indispensability of the physiological nystagmus for vision. Further, it implies a filling-in process since the amplitude of the nystagmus, even with the latter permitted to oscillate the image, would never bring the edge of the image anywhere near the vast majority of the receptors opposite even a 1° spot.

Related to this is the fact that when each of the spots in a fixated pattern disappears in "Traxler's phenomenon," its reappearance is sudden and complete. A tiny eye-movement secures the reappearance—one says, because the spot is now imaged upon unadapted retina. But an eye-movement less than the diameter of the evanished spot would not make the whole spot reappear. A tiny eye-movement (which does suffice) could break the spell of adaptation only for a portion of the contour. What "completes the figure" of the whole spot, if not a physiological filling-in process?

The filling-in process may be caught napping, as we have noted, in the transitory visibility of Mariotte's spot. Perhaps the process can also be defeated, prevented. In the spatial induction of complementary colors, as ordinarily demonstrated, there is no such implication. The

induced chroma may well be helped toward its uniformity of distribution by the filling-in process of my hypothesis. But it has also been reported, more than once, that Mariotte's spot can be seen in a complementary color when projected on a colored field.* Here, perhaps, the induction process and the filling-in process contend for the same area and the former wins. But this leads to the vexed question of what it is that is induced. If it is only complementary chroma, then the filling-in process may be coöperating with the chromatic induction—by supplying the brightness without which the induced chroma could not be visible at all.

For a clear conscience, I must admit that I can think of one monkey-wrench for my own dynamo. It is the contrary nature of "gamma movement." This, one serving of the Greek-alphabet soup of apparent movements, is the apparent expansion of an objectively homogeneous spot of light when it is first switched on. The light appears to grow rapidly from a point to fill the area; and, when the spot is turned off, the light in it seems to shrink to a point as if it were pouring itself down a funnel. This all happens very quickly, but it does take a finite time which one can readily estimate as some fraction of a second.

The gamma movement seen in a light-spot is certainly not the filling-in process caught in the act. For, it goes in the wrong direction: the gamma growth of the lighted area is a filling-*out* process.** Perhaps the centrifugality of gamma movement means that the whole notion of a general filling-*in* process is nonsensical. I do not think so, however. Once a gamma-giving light *is* "filled out," what maintains the homogeneity of its area? I suspect that the gamma-wise lighting up of the area is given entirely by opticus-fiber *on*-effects, and that these may well be faster at the fovea than farther peripherally,† or faster or more prompt at the center of any retinal area suddenly illuminated intensely.

*And even in hemianopia, when the patient views an extensive colored area, he may report the complementary color in his *blind* half-field.

**And a lighted area can subjectively fill from side to side instead of from center to edge—as when two sizable spots of light (not mere dots) are alternated to elicit "phi" movement. Each spot then fills up in the direction away from the other spot—a special case, I believe, of gamma movement.

†It should be easy enough for any skeptic to determine whether gamma movement occurs in a light-spot presented peripherally. The same skeptic might look to see whether the identity of threshold for a spot and an annulus, found by Hecht, Haig, and Wald, holds good when both targets are placed at equal distances from the fovea.

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BOOK REVIEW

THE OPTOMETRIST'S HANDBOOK OF EYE DISEASES. Joseph I. Pascal, O.D., M.D., and Harold G. Noyes, O.D., M.D. Published by the C. V. Mosby Company. St. Louis, Missouri. 300 pages. 155 illustrations. 3 color plates. $9.50. Cloth. 1954.

This is a new book on ocular pathology. In many respects it is a companion text to the "Manual of Ocular Pathology for Optometrists" by Dr. George A. MacElree, of the Pennsylvania State College of Optometry. Like the MacElree text this book is written for optometrists by optometrists and directs the reader's attention to the diagnostic rather than the therapeutic phases of eye care.

The new work by Pascal and Noyes covers all of the diseases of the eye and orbit the optometrist is likely to see in his daily practice and is written in such terms as to meet his every requirement. It includes a section dealing with first-aid measures in both diseased and injured conditions.

As the publisher says—"The Optometrist is sometimes the most important member of the healing professions when it comes to getting the quickest medical or surgical service for the patient." This seems to be exactly what the authors had in mind and as both are optometrists and educators as well as ophthalmologists it is natural that the new text covers the subject thoroughly. The new Mosby book will be a useful addition to your library on eye pathology.

CARL HANSON

RECENT DEVELOPMENTS IN THE PHOTOGRAPHY AND PROJECTION OF WIDE SCREEN AND STEREOSCOPIC PICTURES*

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The "new" forms of motion picture presentation have given rise to numerous problems of common interest to optometrists and to technicians in the motion picture industry. In this paper we shall first consider some of the problems which are more or less common to all of these forms, and thereby provide a background of information for the discussion which is to follow. However, most attention will be given those problems peculiar to the photography of stereoscopic or "3-D" motion pictures. Information which has recently been made available on the processes of binocular vision has been most helpful in the analysis of these problems, and we shall discuss particularly those areas in which such information has been the most useful.

PROBLEMS COMMON TO ALL THE NEW TYPES OF PRESENTATION

Cinerama, CinemaScope, and other "wide-screen" presentations, as well as stereoscopic pictures, all require the transmission of considerably more information from the scene in front of the camera to the screen in the theater than heretofore has been necessary. Unless this additional information can be transmitted, the quality of the projected picture will not equal that of one transmitted by what may be referred to as "standard" methods.

Photography and projection require light as the medium for transmission, and, therefore, in each case more light is required to maintain the standard of quality in these new forms at the same level found in the older methods. The film also forms one link in the transmission process, and, therefore, it too must carry more information than formerly. There are, therefore, two basic problems with all of these new systems, the one having to do with obtaining sufficient light for satisfactory photography, projection, and viewing, the other with obtaining sufficient detail in the film image. In both cases, the increases required to maintain picture quality strictly at present levels are

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difficult and costly to obtain. Therefore, it is important to determine exactly how much, if any, deterioration can be allowed without detracting from the entertainment value of the product. Also, if such be allowed, can one kind of deterioration be better tolerated than another?

Cinerama has solved both of these problems, at least partially, by using approximately six times as large a film area for the projected pictures as is used in standard projection from a single film. Therefore, there is actually more film area per unit area of screen than in standard projection so that definition can be adequate. Each of the three projectors must fill only a portion of the screen area, and does so at moderately short distances so that light levels are also adequately high. The projected pictures are sharp in detail, well lighted, and generally very pleasant to look at.

A drawback, from the visual standpoint, is the obvious mismatch at picture edges and in the color tones and densities of the prints. The mechanical difficulties involved in completely removing these defects, and yet projecting from separate film strips, are such that many consider overcoming them to be beyond the realm of practical possibility. For this reason, development of wide-screen methods, other than Cinerama, has centered around the use of a single film in the photography and projection of the picture.

Two methods have been tried in an effort to obtain at least some of the effects of Cinerama from a single film transmission system. One of these uses anamorphotic lenses as in the Fox CinamaScope. A camera uses such a lens to compress a relatively wide field of view into an aperture only slightly larger than standard. A similar lens is then used in the projector to re-establish the original proportions. Decrease of light intensity on the screen for a given intensity at the aperture is approximately proportional to the increased area of the screen.

The other method employs a shorter focal length of projection lens to increase both width and height of the projected picture. The height of the projection aperture is decreased, however, (usually leaving the width unchanged), to give a greater width-to-height aspect ratio than standard. Here the decrease in light intensity will be approximately proportional to the increase in total area of projected picture before the top and bottom are cut off by the reduced aperture height. Table 1 shows comparative decreases in incident illumination reaching screens having different aspect ratios for a given aperture illumination. The additional losses incurred through projection and viewing filters for 3-D pictures are also shown. It is seen that, in order to maintain light levels

of the order which previously have been considered necessary, effective screen brightness for some forms of presentation must be increased several times over.

TABLE I
INCREASE IN BRIGHTNESS REQUIRED
TO MAINTAIN PRESENT STANDARDS

Screen Aspect Ratio	With Anamorphotic Lens		With Reduced Aperture Height	
	2-D	3-D	2-D	3-D
1.33 to 1	1.00	3.33	1.00	3.33
1.66 to 1	1.25	4.17	1.56	5.20
1.75 to 1	1.31	4.36	1.72	5.75
1.85 to 1	1.39	4.63	1.92	6.40
2.00 to 1	1.49	4.97	2.27	7.55
2.66 to 1	2.00	6.67		

Some of this increase can be gained by using more intense arc sources. This is always accompanied by a change in color balance which may be undesirable, however, and the additional heat at the aperture will cause increased difficulties in the maintenance of proper focus, and may seriously damage the film. Therefore, even with special equipment, an increase of light through present apertures cannot be expected to exceed about 50%. It is obvious that this is not enough.

More promising results are being obtained by directing more of the projected light into the viewing areas by means of directional screens. Previously, matte screens which reflect light so that they are almost uniformly bright in all directions have been used. The aluminized screens required for 3-D projection are quite directional in their characteristics, so that from the best directions they may appear several times as bright for a given illumination as a matte screen. Unless very carefully designed, however, such screens will show streaks and other defects very clearly, and will fall off in brightness as seen from the side seats, or may fall off noticeably from one side to the other even from the better seats. If there are seams, these may take more of the tension causing a panelling effect which will make the seams very noticeable. Serious differences in brightness between top and bottom may be apparent, particularly if projection is from a high angle.

Research directed toward remedying these defects is now going on, and considerable advancement in screen design has already resulted. A particularly successful rigid type of screen, suitable for drive-in, but not for indoor theaters, has recently been engineered by the Research Council and installed in a new 1,000 car drive-in theater. It is hoped that before long the principles used in this design can be incorporated in indoor screens, and that satisfactory screens having a uniform "brightness gain"

of three or four times over matte screens will eventually be generally available. These, with the best available light sources, will largely make up for the losses indicated in Table 1.

Film limitations usually show up as graininess in the projected picture, for definition is limited by the grain size. In order to obtain the short exposure time necessary for motion picture work, negative film generally has larger grain than positive print. Therefore, the best way to reduce graininess is to increase the size of the camera aperture. Much work is being done in this direction now, with larger apertures in ordinary cameras, and special cameras having sidewise film motion being tried. Results are promising, although as usual, each improvement seems to bring its own set of problems. These problems, and the many which have to deal with obtaining sufficient light for satisfactory photography need not be of concern in this discussion, however.

What is of more concern at present are answers to many questions which optometrists and others acquainted with the physiology and psychology of vision may be able to answer. For example: what aspect ratio gives the most pleasing compromise for all types of scenes? What size of picture is the most comfortable to view? Are the larger pictures simply moving the "best" viewing area farther back in the theater, or is there a definite advantage in having pictures which practically fill the field of vision? Can peripheral effects be distracting rather than helpful, and if so, under what circumstances? Are lower brightness levels acceptable in large pictures than in small ones? Can more lower brightness levels be used in stereoscopic pictures than in "flat" ones? How does the distracting effect due to flicker increase with the distance from the center of attention? Why is cross-screen motion so much less acceptable with large pictures than with small ones? Can it be made more acceptable by increasing the projection frequency, or is the effect a psychological one caused by the increased distances and speeds which are involved? Should the lengths of "cuts" from one scene to the next be increased for wide-screen and 3-D pictures? If so, what factors govern the minimum length of time each scene should be shown?

No claim is made that this list is complete, or even that it includes the most important questions. It simply shows the types of questions for which answers must be found if developments in these new media are to proceed intelligently. Some information along these lines is, of course, already available. Much more, it is feared, is known to those who have made a study of visual processes, but is not yet known or understood by the motion picture technicians. And, finally, some of these questions will best be answered by means of the motion pictures them-

selves. Therefore, there is certain to be a mutual benefit derived from close cooperation between those who work with vision and those who make these pictures which depend for their success so completely upon the visual processes.

BINOCULAR VISION AND STEREOSCOPIC PHOTOGRAPHY

Photographers who have worked with steroscopic motion pictures recognized several years ago that projection of these pictures onto screens the size of those used in theaters presented special problems which at that time were not clearly understood. In particular, the mathematical formulations which had been developed solely on the basis of projective geometry did not give good results. On the other hand, comparatively naive attempts which simply set the camera lenses at approximately eye distance apart often gave quite satisfactory pictures even though such settings were completely at variance with the mathematical recommendations.

The difficulty was found in the assumptions which had been made in formulating the projective geometry. Rule[1] in 1941 expressed the thinking which has been current now for several years, namely that a "stereograph is geometrically fixed in direction, distance, shape and size. It is susceptible of only one interpretation instead of an infinite number." On the basis of this assumption, the requirement for successful stereographic projection was laid down that the angles subtended at the eyes of the viewer in the theater by various portions of the projected image should be the same as the corresponding angles subtended at the camera lenses by corresponding portions of the object as it was photographed.

The result of such a requirement was a formulation for setting the distance between the camera lenses, or "interaxial distance" which varied in proportion to the distance from the camera to the object which was being photographed. Generally, for projection on theater sized screens, the recommended interaxial spacings were so small that they could not be obtained with ordinary camera arrangements, and when special mirror arrangements were used which would achieve them, the results invariably showed a phenomenon known as "cardboarding."

In this, the depth between major scenic elements at different distances from the camera was retained, but detailed depth was lost so that the details appeared in planes which were separated from one another as if they were mounted on cardboard cut-outs. It is now known that this phenomenon is entirely due to the use of too small an interaxial spacing.

It is not necessary to establish here the many evidences now avail-

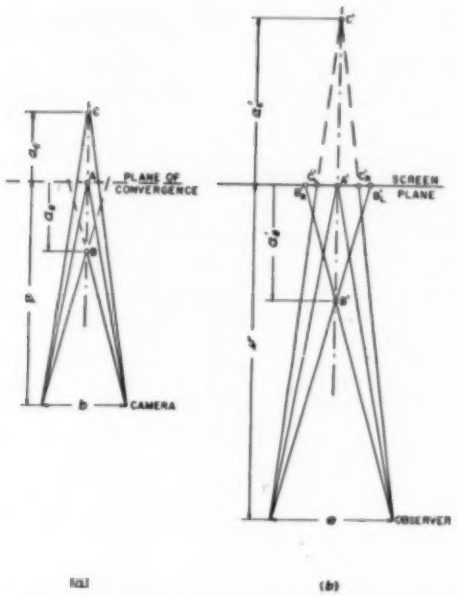

Fig. 1. Lines of Sight in Taking and Viewing Stereoscopic Pictures.*

*NOTE: Figures 1, 2, 3, 4, 5, 6, 7, 8 and 10, are reproduced from the October, 1953, Journal of the Society of Motion Picture and Television Engineers, and are used by permission of this Journal.

able that binocular vision does not, of itself, give an absolute localization in space. Charnwood,[2] Ogle,[3] and Luneburg,[4] for example, all make definite statements based in each case upon extensive observations, to the effect that (quoting Ogle as typical) while "the phenomenon of stereopsis provides a most vivid and accurate relative depth discrimination, absolute localization probably results from a more complex psychic integration of empirical and stereoscopic stimuli."

This information has been most helpful, for translated into mathematical terms, it indicates that the approach to the problem of stereoscopic transmission should be through a study of differential elements rather than of integral distances, and that absolute directions probably do not play the important role that has been assumed for them.

The Motion Picture Research Council has, among its many other duties, that of evaluating the new ideas which are constantly being submitted to the industry. Of course stereoscopic motion pictures have

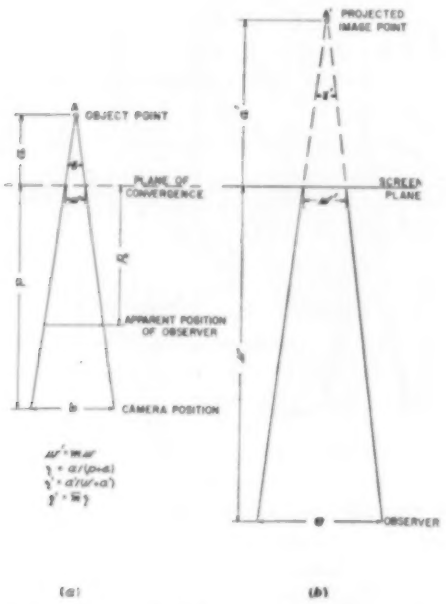

Fig. 2. Geometry of Stereoscopic Transmission.

always been an intriguing subject for inventors so that ideas concerning them have constituted a goodly proportion of those which have had to be evaluated. Available mathematical formulations were quite evidently not correct, so that it was necessary to work out some, and this was done along the lines just suggested.

The success of this effort has been borne out by the fact that the resulting recommendations have been adopted by most of the major studios, and by numerous independent cameramen, both in this country and abroad. Comparative tests have in every instance shown the soundness of the assumptions upon which these recommendations have been made.

It is not the intention here to give a detailed mathematical derivation of these formulations for this has recently been published.[5] However, it will be helpful to show briefly the method that was used and to give the final results. Figure 1 shows a simplified diagram, useful in the analysis of stereoscopic transmission. The distance b is the "interaxial spacing" between the camera lenses and e is the interocular of the observer. The "plane of convergence" is defined as that (approximate) plane in the space in front of the camera containing those pictorial

elements which will coincide in the two projected images on the theater screen. Figure 1 (b) shows the manner in which projected homologous point-pairs (for example C_L' and C_R') fall at two different positions on the screen unless the object point was in the plane of convergence. Lines of sight to these points will, in general, not converge at the screen, but in the example cited will appear to come from a point C', which will be referred to as the projected image point.

Figure 2 considers only one point, which might be either in front of, at, or beyond the plane of convergence. It is convenient to use the distance from the plane of convergence to the object point, shown as a, and the corresponding distance of the image point from the screen, shown as a', to establish the relationship between the object space in front of the camera and the image space in the theater.

The distance between projected point-pairs w' is related to the corresponding distance w in the plane of convergence by the *magnification* m in accordance with the equation

$$w' = m\ w \tag{1}$$

Now for a given w', the ratio of a' to the viewing distance v is independent of this distance. Calling this a *distance ratio* and using ρ' to designate it:

$$\rho' = \frac{a'}{v} = \frac{w'}{w' + e} \tag{2}$$

Therefore, since e is approximately the same for different observers, the distance ratio for a given image point will be practically the same for all observers in a theater regardless of their actual distance from the screen. This is a most important characteristic of stereoscopic transmission for it means that the depth differences between image points increases with increased viewing distances to compensate for the loss of stereopsis at these increased distances. It will be shown later that this compensation is practically complete.

When the object is between the plane of convergence and the camera, the image point will be between the screen and the observer. The distance ratio can then be termed a *nearness* ratio (actually it is the negative of the distance ratio where distances away from camera or observer are considered positive), and plays an important part in the control of forescreen subject matter.

A more convenient ratio for use in transmission problems is the *distance factor* η defined as w/b in the object space or w'/e in the image space. From equation (1) it is seen that

$$\eta' = m(b/e)\eta \qquad \text{or} \qquad \eta' = \overline{m}\,\eta \tag{3}$$

where $\overline{m} = m(b/e)$ can be termed the "reduced" magnification. This equation relates all the essential information in the projected image space and in the object space in front of the camera. The distance factors are related to the distance ratios as follows:

$$\eta = \rho/(1 + \rho) \quad \text{and} \quad \eta' = \rho'/(1 + \rho') \tag{4}$$

This information, as has been pointed out, is not sufficient to form a basis for formulating suitable camera settings. It is granted, of course, that if viewing conditions exactly duplicate conditions in front of the camera, that is, if the magnification is unity, if the viewing distance exactly equals the camera distance, if the interaxial spacing equals the interocular distance, and if all viewing angles are the same, then the visual information given each eye will be essentially the same as if that eye had been in the position of the corresponding lens, viewing the scene through apertures corresponding to those in the camera-projector system. This impression will be obtained for only a single viewing position, however, (referred to as the *orthostereoscopic* position) and the specified conditions are entirely impractical for theater exhibition purposes. What is required is a workable arrangement which will give satisfactory viewing over a fairly large area.

TRANSFORMATION TO BINOCULAR VISUAL SPACE

So far, no consideration has been given to the manner in which the projected images will be perceived through the processes of binocular vision. The suggestion that more than a single interpretation may be given a set of image elements makes possible the finding of relationships such that suitable visual impressions will be obtained by a maximum number of observers as they simultaneously view the projected pictures.

Enough is now known of the processes of binocular vision that it is possible, at least crudely, to establish a mathematical transformation relating projected image space and perceptive visual space. Therefore, some idea may be obtained of the manner in which images obtained from different types of camera settings will be interpreted under various viewing conditions, and these can be used to guide experimental work so that development of satisfactory specifications for stereoscopic photography need not proceed blindly.

A convenient coordinate system for this purpose is that referred to by Luneburg[6] as "modified bipolar coordinates." Figure 3 shows these as related to the "Vieth-Müller" circle through the nodal points of the two eye-balls and the point of fixation. The *angle of elevation* (θ) is that of the line of sight above the horizontal plane through the eyes. The *bipolar* latitude (ϕ) is the angle between the line of sight (from either eye) with the direction to the intersection of the circle

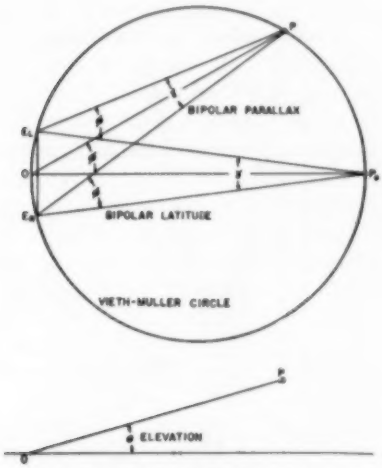

Fig. 3. Modified Bipolar Coordinates.

with the meridianal plane. The *bipolar parallax* (γ) gives the *angle of convergence* of the lines of sight. In this system, small displacements normal to the line of sight in the vertical plane will affect θ only, displacements along the Vieth-Müller circle will affect ϕ only, and displacements along the lines of sight will affect γ only.

The Motion Picture Research Council made the assumption, in establishing its stereoscopic formulations, that it would be desirable to have the dimensional proportions of the apparent image—in the perceptive visual space of the observer—the same when the projected images were viewed in the theater as they would have been had the observer witnessed the scene directly from that point at which it apparently was photographed.

Since horizontal and vertical dimensions (at any given distance from the camera) can be expected to retain their proportions in any photographic system, consideration needs be given only to the proportion between one of these and the "depth" in directions along the lines of sight. To clarify the assumption regarding the apparent observer position, it must be pointed out that only at one viewing distance will a picture have the same perspective as the original scene presented to the camera. At all other viewing distances the perspective will appear as if —in localized planes at least—the observer had been at other than the camera position. Therefore, it is necessary in establishing settings for any particular shot to determine this apparent observer position in

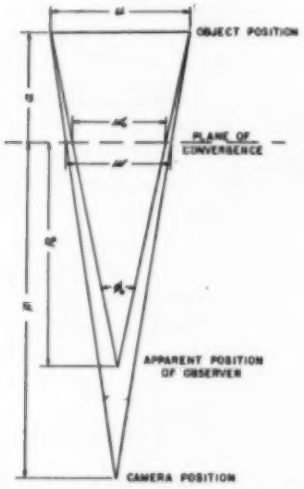

Fig. 4. Apparent Position of Observed in Viewing an Extended Object.

terms of the focal length of lens and the best viewing areas as related to the screen size in the theater.

The relationship of the bipolar latitude and parallax angles to

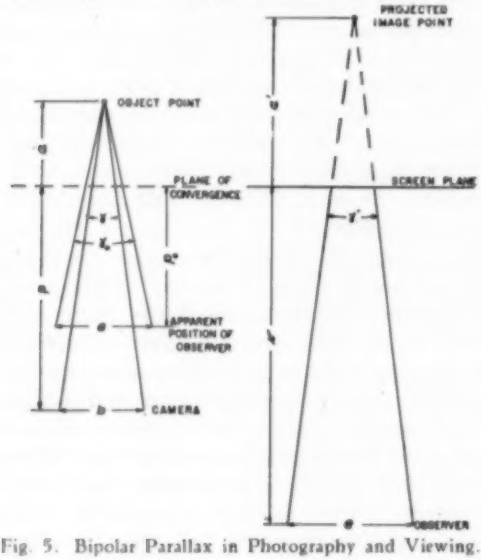

Fig. 5. Bipolar Parallax in Photography and Viewing.

those factors which have already been established are shown in Figures 4 and 5. The subscript ($_o$) is used for values related to the apparent observer's position, and, of course, the "stereobase" at this position is always the interocular distance rather than the actual interaxial spacing of the camera lenses since the assumption has been made that the picture will appear as if the observer had actually been at this position.

Remembering that binocular vision provides information on differential rather than on absolute values, the basic assumption can then be interpreted in terms of the width and depth coordinates, ϕ_o and γ_o respectively, at the apparent observer's position, and ϕ' and γ' at the position of the observer in that theater. The required relationship is that

$$\frac{d\phi}{d\gamma_o} = \frac{d\phi'}{d\gamma'} \tag{5}$$

Using this relationship and those which have already been given, it is found that the interaxial spacing b for the photography of an object a distance from the plane of convergence when the camera is at p distance in front of this plane, and the apparent position of the observer is at p_o distance is

$$b = e\,\frac{p + a}{p_o + a} \tag{6}$$

(e is the interocular distance).

This relationship as derived holds, of course, only for infinitesimal areas. In order to check its validity for regions of finite size, it is necessary to use a transformation from projected image space to visual space, and integrate along geodesics in the visual space. Luneburg[6] has suggested just such a metric under viewing conditions which approximate those in a theater. For this reason, his transformation has been used to check the validity of the above equation. The metric which he suggests for visual space is given by

$$ds^2 = \operatorname{csch}^2\sigma\ (\gamma + \mu)\ \ (\sigma^2 d\gamma^2 + d\phi^2 + \cos^2\phi d\theta^2) \tag{7}$$

where ds is the differential unit of length, σ and μ are constants which vary slightly from one individual to another, and the angles are the modified bipolar coordinates previously defined.

Integrating along those geodesics obtained by allowing only one of the coordinates to vary in turn, it is found that finite distances in vertical planes are given by

$$s\theta = (\theta_2 - \theta_1)\ \operatorname{csch}\tau\cos\phi \tag{8}$$

where $\tau = \sigma\ (\gamma + \mu)$

Likewise distances along Vieth-Müller circles will be given by

$$s\phi = (\phi_2 - \phi_1) \operatorname{csch} \tau \tag{9}$$

and distances along the lines of sight are given by

$$s\gamma = \log_e \tanh (\tau_2/2) - \log_e \tanh (\tau_1/2) \tag{10}$$

These distances are all angular, of course, but it must be kept in mind that these are the very angles which the eyes detect, and it is these, rather than any linear distances, which are actually seen.

Using these values, it is possible to plot relationships of finite dimension ratios in order to see how closely these conform to each other as determined from conditions at the apparent observer's position in the object space, and from the observer's position in the theater for the projected image space. In short, if the basic assumption is to hold for finite regions, then

$$s\gamma'/s\gamma = s\phi'/s\phi = s\theta'/s\theta \tag{11}$$

or again assuming that width and height will probably retain their proportions anyway, and using the first of the above equations, it should be possible to show that

$$s\gamma'/s\gamma = s\phi'/s\phi \tag{12}$$

for any photographic system which satisfies the basic assumption.

Curves showing these dimensional proportions for typical conditions are shown in Figures 6, 7, 8, and 9. Figures 6, 7 and 9 use

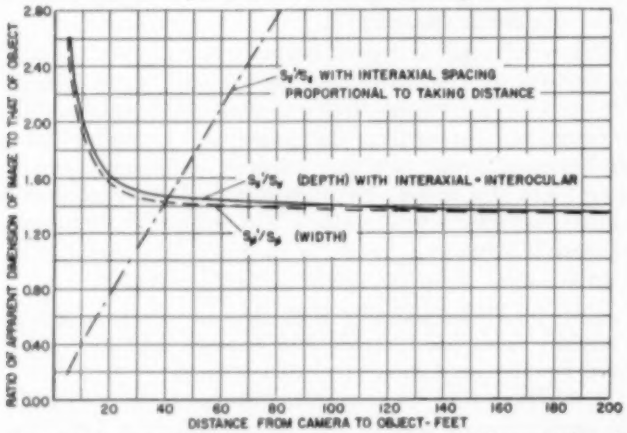

Fig. 6. Ratios of Integrated Dimensions in Projected Image to Corresponding Apparent Dimensions in Object. These curves were calculated using equations (9) and (10) under the following assumed conditions: Viewing distance in theater is 40 ft., screen width is 24 ft., object has a depth of 3 ft., and near edge is in plane of convergence at all camera distances. Focal length of camera lenses is 2 inches. Interaxial spacing for solid curve is 2.5 inches.

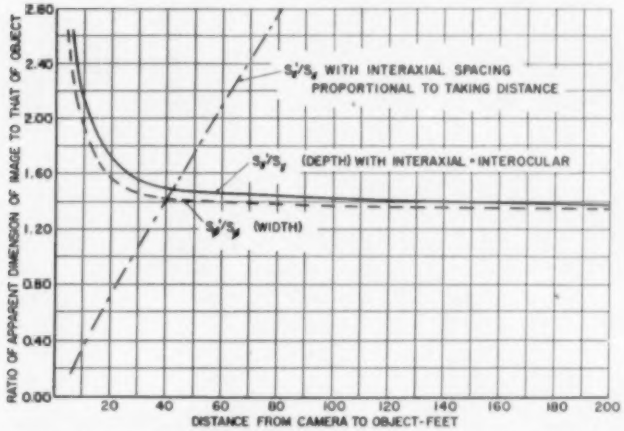

Fig. 7. Ratios of Integrated Apparent Dimensions in Projected Image to Corresponding Apparent Dimensions in Object. These are calculated under the same assumed conditions as those in Figure 6, except that the object is assumed to have a depth of 20 feet.

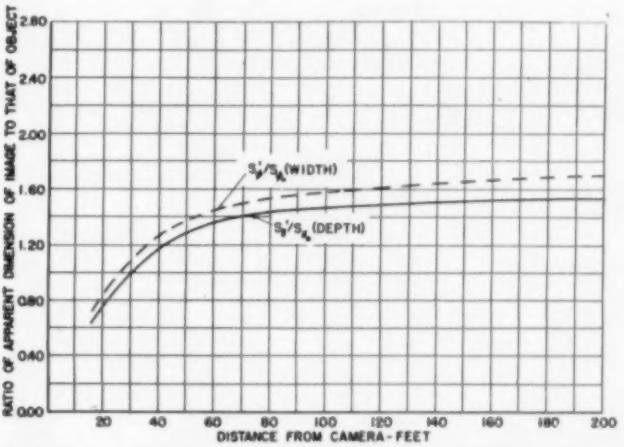

Fig. 8. Ratios of Integrated Apparent Dimensions in Projected Image to Corresponding Apparent Dimensions in Object Where the Observer Is Apparently Between the Camera and the Object. In these curves, the object depth is assumed to extend from the plane of convergence back to the indicated distance from the camera, and therefore varies with distance, whereas in Figures 6 and 7, it was assumed to be constant. Here the plane of convergence is assumed to be kept at a constant distance of 30 feet from the camera. Screen width is 24 feet and viewing distance is 700 inches or 58.3 feet. Focal length of camera lenses is 3 inches and interaxial spacing is fixed at 3.5 inches. This gives a picture which appears as if viewed from a point 20 feet in front of the plane of convergence.

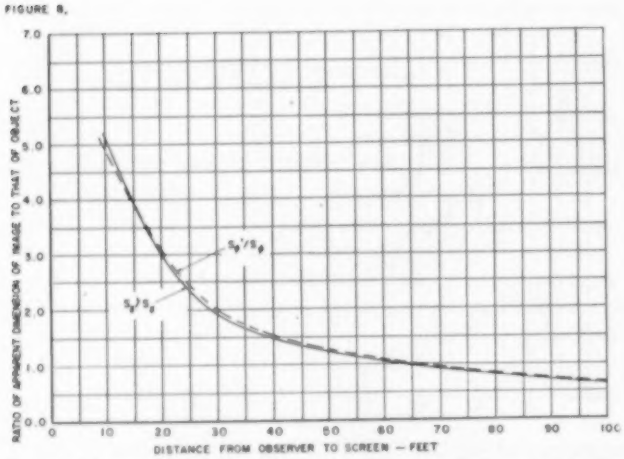

Fig. 9. Ratios of Integrated Apparent Dimensions in Projected Image to Corresponding Apparent Dimensions in Object as Viewed from Different Distances in the Theater. Camera distance to plane of convergence and front edge of object is fixed at 20 feet. Object depth is 3 feet. Lens focal length is 2 inches, and interaxial spacing is 2.5 inches. The close coincidence of these curves at all reasonable viewing distances shows the practically complete compensation for decrease in stereoscopic depth accomplished by the increased distortion in the projected image for longer viewing distances.

lenses of such focal length that $p_o = p$. The plane of convergence in each case was assumed to be at the front of the object. In Figure 8 the plane of convergence was assumed to be kept constant at 30 feet from the camera, and the object distance or depth varied. Figure 9 shows the proportions as viewed from varying distances in the theater. In Figures 6 and 7, curves are included to show the depth proportions as obtained with camera settings following the rule that interaxial spacing will vary proportionally to taking distance. The intersection of each of these curves with the "width" curve is the orthostereoscopic position. It is readily evident that, except at this one point, dimensional proportions will appear badly distorted.

Many such relationships have been studied, under various types of conditions, and all show that, when the conditions of equation (5) hold, that is, when settings are made in accordance with equation (6), then equation (12) also holds within satisfactory limitations. Several motion pictures have been made, and numerous other photographic tests have been made, using these assumptions, and all have shown good proportionality. This close agreement of test results with theory, incidentally, serves to verify the validity of Luneburg's assumptions and indicates that the transformation suggested by the metric of equation

(9) is apparently a very useful one for predicting the visual perception obtained from a given geometric configuration.

SPECIAL TREATMENT OF CLOSE-UPS

A very important phychological factor which is often used in motion pictures has been disregarded in the discussion up to this point. It has long been the custom to induce in the observer a feeling of nearness to the actors by using "close-up" techniques. Actually, the projected image is considerably giantized, even as compared with the remainder of the picture. Over the years, however, theater goers have come to accept this giantization and no longer regard it as unnatural. In the photography of stereoscopic pictures, it has been found that proper allowance must be made for this giantization, if proportions and perspective are to retain their "natural" relationship. In short, it is necessary to photograph close-ups so that they will appear to be giantized stereoscopically as well as photographically. This is accomplished by reducing the interaxial spacing by an empirically determined "giantizing" factor G in accordance with the equation

$$b = \frac{e}{G} \frac{(p + a)}{(p_o + a)} \tag{13}$$

This factor turns out to be a function of the magnification which has been defined previously, and the relationship which gives the most acceptable results as determined from numerous photographic tests is shown in Figure 10. For magnifications of less than 3, that is, for a

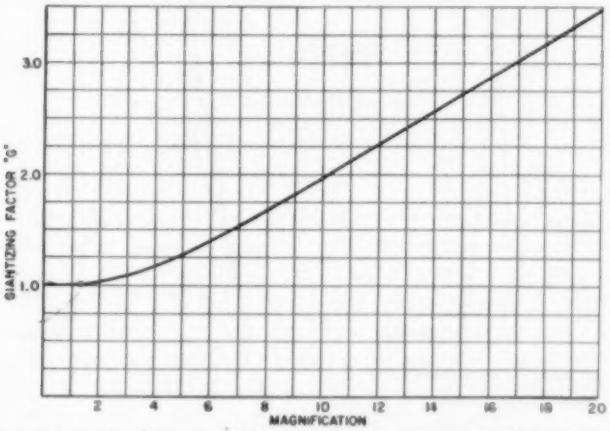

Fig. 10. Relationship Between the Giantizing Factor "G" and Magnification. The factor "G" is that required in equation (13), and the magnification is that defined by equation (1).

full height figure to less than fill an 18 foot high screen, this factor has a value of essentially unity. A "waist" figure close-up having a magnification of 8 would have G = 1.65 while for a full-head close-up (12" high filling the screen height) G would have a value of 3.2. In each case, interaxial spacings must be reduced proportionally in order to give best results.

BACKGROUND DIVERGENCE

Unless almost impossible restrictions are placed upon camera settings, conditions will often arise similar to those shown in Figure 11 where lines of sight to projected homologous point-pairs will actually diverge. Such a condition is never encountered in natural viewing, and so the assumption has quite reasonably been made that it should never be allowed in the projection of stereoscopic pictures.

Perhaps in no phase of the development of practical techniques for taking these pictures has information on the processes of vision played such a vital role as in showing that good vision is possible even when these lines of sight diverge. Fry and Kent,[7] using base-in and base-out prisms have shown that stereo-acuity is fully as sharp with slight diver-

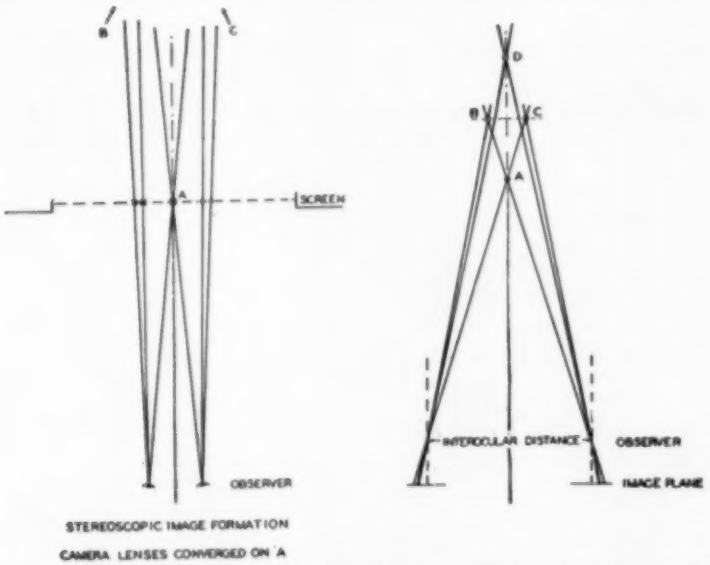

Fig. 11. Photographic Conditions Which Give Rise to a Divergence of Lines of Sight to Background Objects. Image points for B′ and C′ are well back of screen plane, and lines D′ diverge. Nevertheless under certain limited conditions D′ will be seen in single vision.

gence as with an equivalent amount of convergence. In fact, from their researches, it appears that clear, single vision is possible with total divergence angles in excess of 5°. From this work, and after consultation with Dr. Max Schapero of the Los Angeles College of Optometry, it was decided to recommend the use of slight divergence for extreme background conditions, but to limit it in all cases to not more than about ½ degree for each eye at normal viewing distances, or one degree per eye (a total of 2 degrees) for the most extreme viewing positions. This means in practice that for projection on a screen 24 feet wide, maximum separation of homologous points will not exceed 11 inches. Incidentally, it is interesting to notice that Luneburg's formulations indicate that such a limited divergence may be possible, for the γ value can be negative without making τ negative. The value he indicates for μ for one individual is 0.0809 radians or about 4½°, which in turn is the limit of negative parallax which can be allowed without making τ negative. This is in close agreement with the information given by Fry and Kent.

The manner in which this use of divergence of lines of sight has allowed considerably more freedom in camera settings is best shown in Table 2.

TABLE 2

Condition	Specified Setting With no Divergence	Setting MPRC System
f = 2 in. Distance to object (plane of convergence) is 10 ft. Interaxial	0.43 in.	1.9 in.
f = 3 in. Waist figure close-up. Interaxial	0.29 in.	2.1 in.
f = 2 in. Distance to plane of convergence is 10 ft. Distance from plane to farthest point in set (interaxial —2.5 in.) should not exceed	2 ft. 1 in.	31 ft.
Same but with interaxial spacing recommended in first line	6 ft. 8 in.	Infinite
f = 2 in. Distance from camera to plane of convergence, if infinitely distant points are also in scene, using 2.5 in. interaxial	58 ft. 4 in.	13 ft. 3 in.

It is possible in each case to obtain the values specified in the MPRC (Motion Picture Research Council) system without difficulty, whereas those required by the condition that no divergence take place are completely impractical. Furthermore, if such small interaxial settings were used as recommended in the first two settings, cardboarding would almost certainly be present in the projected pictures. In short, without allowing for this slight divergence, it would be impossible to photograph stereoscopic pictures for theater screen projection.

RECOMMENDATIONS FOR FORE-SCREEN SUBJECT MATTER

The basic assumption which has been made is that subject matter

as viewed in the theater will appear *as if* it were seen from some point which usually is considerably nearer the subject than the viewing distance in the theater. This means that actually the depth in the projected images is greatly distorted to give images the same "see-around" when viewed at observer to screen distance as the original objects had when viewed from camera position or from the apparent position of the observer.

If no reference points of known separation are available, this distortion will pass undetected. For example, when the image points are all at or behind the screen plane, there is never any difficulty. However, when the image points are fore-screen, there is always the likelihood that some object or objects at known distances from the observers will serve as reference points to disclose the actual distortion in depth and thus destroy the illusion.

Fortunately, this effect is usually not noticeable if the distance forescreen is less than half way from the screen to the observer—in other words, if the nearness ratio is less than 0.5. At such distances, stereoscopic depth between real objects in the theater is not too apparent, and the illusion in the picture will pass for what is intended. At ratios larger than this, however, there is more and more likelihood that the distortion in the image will be apparent. The amount of it, and the certainty of its appearance depend upon the ambient light levels in the theater, and the nature of the scenic elements. Its distracting effect will depend largely upon the mood and critical level of the viewing audience. With all forescreen subject matter, and in particular with that which has nearness ratios in excess of 0.5, the accommodation-convergence relationship causes difficulty in viewing. This, of course, comes from the unnatural relationship imposed by having the eyes converge on image points which may be comparatively close while maintaining accommodation at the screen.

Here again, optometric studies have been most valuable in guiding development of practical recommendations. Hoffstetter[8] has summarized considerable work along these lines and interpretation of his data indicates that single binocular vision will rapidly become increasingly difficult for most observers at nearness ratios exceeding about 0.8.

Experience has shown that in general forescreen subject matter is more difficult to see—possibly because of the accommodation-convergence relationship—than that which is kept severely at or behind the screen plane. However, there are so many advantages in bringing it forward, at least part of the time, that attempts are constantly being made to do so, often with little understanding of or regard for the difficulties involved.

The Research Council has recommended that any subject matter with nearness ratios larger than 0.5 be kept in the field of view only for a short time, and that it either be introduced into the scene at lower nearness ratios to allow time for suitable fusion or that it quickly move into regions of lower nearness ratio. Further, recommendations are that no objects which are to be seen clearly should come nearer than a ratio of about 0.8. In fact, the two "near-points" at 0.5 and 0.8 are to be clearly marked for each camera setting, and are used in the proper control of this subject matter.

While this discussion has not treated all of the problems which have arisen, it has shown several in which considerable help has been received from researches in the binocular vision processes. It seems elementary to say that successful photography and projection of stereoscopic pictures cannot proceed without a thorough understanding of these processes. Sad to say, most of the photography which has to date been released has been made with little regard for what is known about the way we see, or with little attempt to understand what is known. Fortunately, many of the major pictures which are in process or but very recently released, have used the information given here to some extent, and almost certainly it will be used more and more in forthcoming pictures. There is little question that where it is used, the results are much more natural in appearance, and are much easier to view than are many of the pictures which previously have been so hurriedly and literally thrown at the public.

In these developments the Research Council and the major studios which it represents have been most grateful for the wonderful help and cooperation which have been received from the extensive studies in the field of binocular vision to which reference has already been made, and especially for that which has been received directly from many optometrists who have given liberally of their time and information to assist with this program.

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TRANSACTIONS OF THE AMERICAN ACADEMY OF OPTOMETRY

A department devoted to announcements, reports, appointments, organization data, news, professional problems and ideals, as these relate to the Academy.

ACADEMY LUNCHEON AT A.O.A. MEETING

Dr. Meredith W. Morgan, Jr., president of the Academy, and Dr. James F. Wahl, president of the A.O.A., spoke briefly at the Academy luncheon held June 22 at the annual meeting of the A.O.A. in Seattle, Washington. Forty Academy members attended the luncheon.

RESERVATIONS FOR TORONTO MEETING OF ACADEMY

Members of the Academy should now start planning their trip to Toronto, Ontario, Canada, to attend the annual meeting of the Academy in that city, December 11-14, 1954. Hotel reservations may now be made direct with the Royal York Hotel. Members are urged to room together, two-in-a-room, as the majority of the 180 rooms set aside for use by Academy members and guests are double rooms and there is a considerable saving in such doubling up. Get in touch now with a member and arrange to share a room with him at Toronto.

PAPERS AND PROGRAM COMMITTEE

Dr. John D. Perry, Jr., chairman of the Papers and Program Committee for the Toronto meeting, reports a good response to his "call-for-papers" for this four-day session. There is still room for additional papers on the program and members planning to present these should write Dr. Perry at once. Also members planning to present papers or clinical reports at the Section meetings, dealing with the specialties, aniseikonia, contact lens fitting, orthoptics, occupational optometry and pathology should write the Section chairmen or Dr. John D. Perry, Jr., 304 O'Hanlon Bldg., Winston-Salem, North Carolina, promptly.

A NOTE ON THE SHEARD COMMEMORATIVE VOLUME

The committee working on the Sheard Commemorative Volume reports that the first four sections of this commemorative book are now complete and that the last two sections are now being edited.

THE EFFECT OF LUMINANCE OF THE CONTRAST INDUCING FLASHES ON THE SPATIAL RANGE OF METACONTRAST*

Mathew Alpern†
College of Optometry, Pacific University
Forest Grove, Oregon

Metacontrast is the reduction of the brightness of a flash of light when it is succeeded by a second flash which is exposed in an adjacent region of the visual field. The literature on this phenomenon has been reviewed in a previous paper.[1]

Certain of the characteristics of this phenomenon have been investigated in some detail.[2] In order to describe the variables most easily

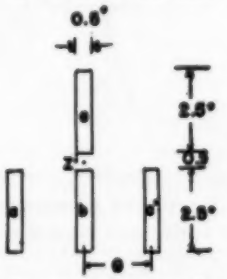

Fig. 1. Stimulus pattern for the metacontrast experiment. The comparison standard (*a*) seen by the left eye remains at a fixed luminance of 10 ft.-L. The test patch (*b*) seen by the right eye has a luminance which is varied as required to make a brightness match with the comparison standard. The two contrast inducing patches (*c* and *c'*) also seen by the right eye have a luminance which in the present experiments was varied from 1 to 1,000 ft.-L. The angular separation of the center of the contrast inducing patch from the center of the test patch (θ) could be varied from continguity ($\theta = 0.5°$) to $\theta = 5.0°$.

reference can be made to Figure 1 which illustrates the experimental targets used in these experiments. The comparison target (*a*) is seen by the left eye, while the test patch (*b*) is seen by the right eye. The two patches (*a* and *b*) were always flashed together and the experiment consists of the experimenter varying the luminance of the test patch until the two appeared equally bright. Metacontrast was induced by the two contrast inducing patches (*c* and *c'*) which were also exposed

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to the right eye. The time interval between the exposures of (*a-b*) and (*c-c'*) could be systematically varied. At each exposure asynchrony the luminance of the test patch required to make it equal the comparison patch in brightness was determined as the dependent variable. The

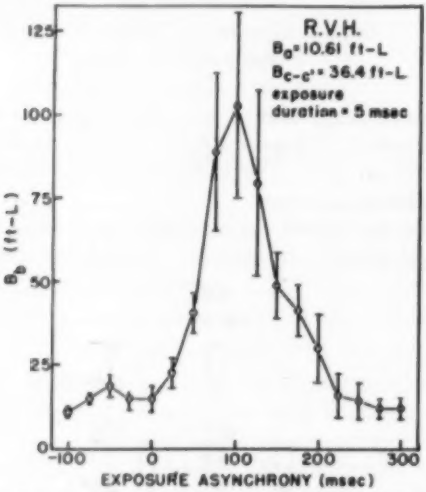

Fig. 2. Typical results of metacontrast experiment. The ordinates are values of the luminance of the test patch required to make a brightness match with the comparison standard. The abscissas are time intervals between the onset of the test-comparison flashes and that of the two contrast inducing flashes in milliseconds. Positive abscissas: The contrast inducing flashes followed the test-comparison flashes. All flashes: 5 msec. duration. Comparison standard: 10 ft-L. contrast inducing flashes: 36 ft.-L. Angular separation ($\theta = 0.75°$) Data from Alpern.[2]

method of limits was used. The results of a typical experiment are illustrated in Figure 2. In this figure the ordinates are values of the luminance of the test patch required to make it equal the comparison standard in brightness while the abscissas are values for the time interval between the exposure of the test patch comparison standard and the exposures of the two contrast inducing patches. When the contrast inducing patches followed the exposure of the test-comparison patches the values are plotted as positive.

When the contrast inducing patches precede the test-comparison flashes there is a small inhibitory effect but experiments seem to indicate that this is not closely related to metacontrast.[2] The metacontrast effect increases as the asynchrony increases to a maximum value at about 100 msec. and then decreases to a zero value as the time interval between the exposure of the test-comparison patches and that of the two

contrast inducing patches reaches 200 msec. Increasing the luminance or duration of the contrast inducing patches or decreasing the luminance or duration of the test-comparison patches is associated with an increase in the magnitude of the effect, as is decreasing the angular separation of the center of the test patch from the center of the contrast inducing patches. If the test and comparison patches are confined to the 2.5° center of the visual field the effect disappears but changing fixation just slightly so that the test and comparison patches are viewed with a very slight eccentricity immediately is associated with a marked metacontrast effect.

All these conclusions are based on the results of previous experiments.[2] In attempting to build an explanation for these data two hypotheses have been suggested:

1. The interaction occurs between the neural events produced by the first flash and those by the second flash, presumably at a synapse within the visual pathways.
2. The interaction occurs between the neural events produced by the first flash and extraneural events produced by the second flash. (Several different possibilities have been suggested to account for the "extraneural" events. One of the most reasonable being that it is comparable to the inhibitory electrical effect of the electroretinogram described by Granit as the P-III process.[3])

The available evidence does not allow for a conclusive decision between these two hypotheses. It has been shown that the metacontrast effect remains operant only over a very small separation of the center of the test and contrast inducing patches but the behavior of this spatial range as the intensity of the contrast inducing flashes is varied has not been studied previously. The present experiments were designed to investigate this matter. Such experiments are of theoretical importance since the two hypotheses described above predict rather different results from them.

APPARATUS AND PROCEDURE

The experimental apparatus which allowed for the presentation of the test situation illustrated in Figure 1 is illustrated in Figure 3. This apparatus has been described in detail elsewhere.[4] The optical system is designed to form images of the aperture stops in the planes of the entrance pupils of the two eyes. These images were smaller than the smallest possible entrance pupils and consequently served as artificial pupils for the observers. The technique employed is the binocular brightness matching procedure. The apparatus allows for the variation of the intensity of the test patch, the comparison standard and the two contrast inducing patches independently as well as the durations of the contrast inducing and test-comparison patches. The time interval between the exposures of the test-comparison patches and the two con-

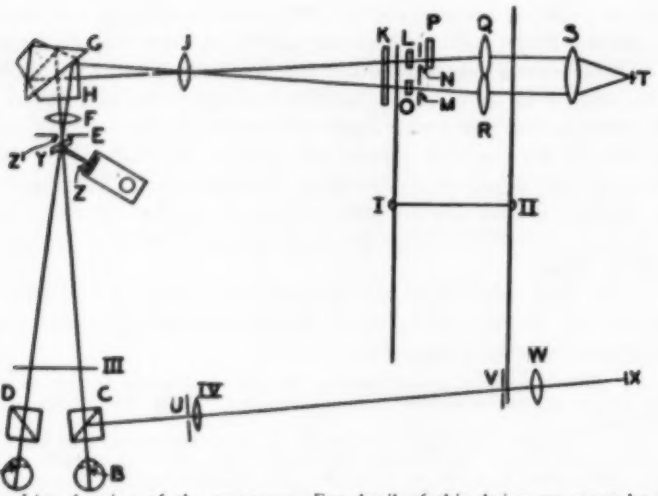

Fig. 3. Line drawing of the apparatus. For detail of this design see paper by Fry and Alpern.[4]

trast inducing patches could be varied systematically from —100 to 300 msec. The spatial separation of the center of the contrast inducing patches from the center of the test patch could be varied from contiguity to 5°.

Using the method of limits the observer made a brightness match of the test-comparison patches when the contrast inducing patches were occluded. The contrast inducing patches were then exposed simultaneously with the test-comparison patches, and the brightness match was obtained again. The contrast inducing patches were then exposed 25 msec. after the test-comparison patches and the brightness match was repeated. In this way brightness matches were made with the test-comparison patches followed by the contrast inducing patches in 25 msec. steps from zero to three hundred milliseconds. This constituted one experimental run. Experimental runs were made with the outer edges of the test patch contiguous with the inner edges of the contrast inducing patches and at separations of the centers of the two of: 0.75°, 1.0°, 1.5°, and 2.5°. At each of these positions measurements were made at luminances of the contrast inducing patches of: 1, 10, 100, and 1000 foot-lamberts. All measurements were made on one experienced observer.

RESULTS

The results of these experiments are illustrated in Figure 4. In the

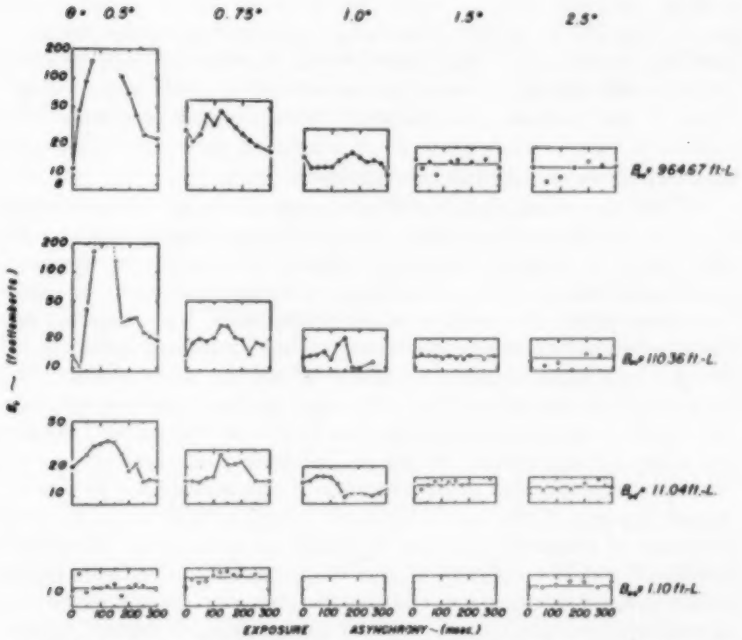

Fig. 4. Variation in the magnitude of metacontrast as a function of luminance of the contrast inducing flashes and angular separation of the center of the test object from the centers of the contrast inducing flashes. Observer E.M. luminance of comparison standard: 10 ft.L. all flashes: 5 msec. duration.

figure each graph represents the data for one experimental run. In each graph the ordinates represent the amount of metacontrast as evidenced by the value of the luminance of the test patch (plotted on a logarithmic scale) required to make the brightness match with the comparison standard which remained fixed at 10 ft.-L. while the abscissas are values for the time interval in milliseconds between the exposures of the test-comparison flashes and the two contrast inducing patches. The various graphs have been arranged in such a manner that each column represents runs at the same separation of the centers of the contrast inducing patches from the center of the test patch (increasing from left to right successively from 0.5° to 2.5°) while each horizontal row represents runs at the same luminance of the contrast inducing patches (increasing from bottom to top from 1 to 1000 ft.-L.).

These results are in harmony with previous data which show an increased metacontrast effect with increase in the luminance of the two

contrast inducing patches. They also show the rather abrupt decrease in the magnitude of the effect with increased separation found in previous experiments. The shift in the maxima of each graph as intensity and separation varied is not obvious in these data as it is in those of the previous experiments.[2] Whether these discrepancies are matters of experimental errors or of individual differences in observers can only be decided by further experiment.

The most startling fact which may be concluded from these data is that as the luminance of the contrast inducing patches was increased from 10 to 1000 ft.-L. the rather marked increase in the magnitude of the metacontrast was not associated with any increase in the spatial range over which the metacontrast effect operated. This range remained for all luminance values from contiguity to somewhere between 1.0° and 1.5°. If metacontrast is a matter of an inhibitory electrical field associated with the second flash reducing the electrotonus in the visual pathways of the excitation of the first flash and consequently reducing the neural events therein as the second hypothesis suggests[5] then it would be expected that as the intensity of the second flash increased so would the size of the inhibitory field and as a consequence so would the range of interaction. It can, of course, be argued that the range of intensities was not sufficiently large to produce an appreciable increase in the range of interaction and in this sense the present experiments cannot be regarded as crucial. It seems unconvincing, however, to pursue this line of reasoning at any length since the intensity variation was large enough to produce almost a twenty fold increase in the amount of inhibition while the range during this same intensity change was not increased even by as little as one-half a degree.

Even with the hypothesis that metacontrast is a matter of the interaction of the *neural events* produced by the two flashes it would not have been too unusual to find that increasing the luminance of the second flash increased the range of interaction in view of the extreme synaptic complexity of the visual pathways.[6] The present findings, that increasing the luminance of the contrast inducing patches has no measurable effect on the spatial range of interaction in metacontrast suggests all the more strongly that certain anatomical factors must limit the range of interaction. The nature of these limitations must await further experimental analysis but the present results clearly support the hypothesis that metacontrast is a matter of the interaction of the neural events produced by the first flash and the neural events produced by the second flash.

It is, of course, a rather simple matter to compose some *ad hoc*

hypothesis to bring the above experimental data into line with the hypothesis that metacontrast is a matter of the interaction of the neural events produced by the first flash with the extraneural events produced by the second flash. This scarcely seems a fruitful approach, however, without some further evidence to justify it.

SUMMARY

Measurements of the magnitude of metacontrast as the luminance of the contrast inducing flashes was varied from 1 to almost 1,000 ft.-L. on one experienced observer showed no increase in the spatial range of metacontrast with increase in intensity of the contrast inducing flashes. These data suggest that metacontrast is a matter of the interaction of the neural events produced by the first flash with the *neural events* produced by the second flash rather than the interaction of the neural events produced by the first flash with the *extraneural* (electrical) events produced by the second flash.

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ABSTRACTS

BLINDNESS IN PRESCHOOL CHILDREN. C. Edith Kerby. Sight-Saving Review. 24.1.1954.

2,800 blind children under seven years of age were examined in 22 states. The author estimates from these findings as well as other data that 24.6 per 100,000 population under seven years of age have a binocular corrected visual acuity of less than 20/200. In approximately 50 per cent of these children the blindness is caused by retrolental fibroplasia which is of unknown origin.

WILLIAM V. BALL

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PENNSYLVANIA STATE COLLEGE OF OPTOMETRY WINS NEW HONORS

The profession is aware that the quality of undergraduate optometric professional education as supplied by our independent optometric colleges has steadily improved during the past decade. These non-profit institutions have been continuously up-grading their teaching facilities, their faculties and their physical plants. They have been determined to make their respective institutions second to none in professional training. How well they are succeeding is shown by the recent step taken by the Middle States Association of Colleges and Secondary Schools.

At the April meeting of the Commission on Institutions of Higher

Education of the Middle States Association of Colleges and Secondary Schools, the Pennsylvania State College of Optometry was accredited by that organization and voted into membership.

The Middle States Association is the regional accrediting agency for universities, colleges and high schools located in the states of New York, New Jersey, Pennsylvania, Maryland, Delaware and the District of Columbia. It is the largest accrediting agency from the standpoint of the number of educational institutions in its area. Prior to 1954, the Middle States Association, and the other regional accrediting agencies, evaluated and accredited only institutions of liberal Arts and Sciences, and left the accreditation of professional educational institutions to be done by the professions concerned. Thus, the Pennsylvania State College of Optometry becomes not only the first school of optometry to be accredited by a regional agency, but also one of the first professional schools in the country to be so recognized.

Before undertaking its evaluation of the Pennsylvania State College of Optometry, the Commission on Institutions of Higher Education of the Middle States Association of Colleges and Secondary Schools entered into working agreements with the Council on Education and Professional Guidance of the American Optometric Association, and the Pennsylvania Department of Public Instruction. Under the conditions of these agreements, the evaluation of the college was made jointly by the three organizations. An evaluation committee composed of representatives of the three groups inspected the college in February, 1954. Prior to the visit of the committee, the college was required to supply extensive information and facts relative to all phases of its operations, to serve as a basis for the evaluation.

This new step is most significant in optometric undergraduate professional education, and indicates that our independent optometric colleges are rapidly reaching a plane of genuine excellence for which the profession can be proud. To the Pennsylvania State College of Optometry—a leader of the independent optometric college group for years—goes the distinction and honor of being the first optometric professional school to achieve this splendid recognition. This is a fine thing for the Pennsylvania State College of Optometry, and a fine thing for optometry—and the students enrolled in this outstanding educational center.

This well deserved recognition is also a tribute to the Council on Education and Professional Guidance of the American Optometric Association who were invited by the Middle States Association of Colleges and Secondary Schools to assist them in making their evaluation of Penn State. We are pleased, too, in reporting that the Middle States

Association found our own professional accrediting agency doing such a fine job. The entire activity, culminating in its successful accreditation is an event of major importance in optometric education.

CAREL C. KOCH

SPECIAL REPORTS

THE PREPARATION AND DEVELOPMENT OF A DICTIONARY OF VISUAL SCIENCE*

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The critical examination of existing dictionaries related to vision brings to light a number of common limitations. They usually cover a relatively small portion of the terms currently used in certain areas of visual science. Of the terms which are listed many have definitions containing restricted and often obsolete meaning. In many cases the definitions are confined to a single concept, failing to include various other meanings which are commonly conveyed by the term. Some of the dictionaries are encyclopedic in nature, providing extensive detail, and hence considerable reading to disclose the meaning of a single term. Also since the existing dictionaries are not designed to give broad coverage in all the visual sciences, nor are even comprehensive within a specific visual field, there are in many cases commonly used terms not even listed.

In view of the obvious intent and purposes of the various existing dictionaries, and the many restrictions which are forced on compilers and authors to meet publication demands, these observations cannot be regarded as criticisms of the quality of the work. Rather, they serve to point up the handicaps faced by students and practitioners in the field of vision who are forever in need of a reasonably comprehensive reference

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that will serve as a key to the terminology more or less peculiar to the visual sciences.

Over six years ago the need for a modern comprehensive dictionary covering the terminology of the visual sciences was especially felt by the two senior authors. The work started with a compilation of terms peculiarly characteristic to optometry, as a partial fulfillment for the degree, Doctor of Optometry. As a preliminary study, a survey of recognized authorities in the field of optometry was conducted to obtain their reactions toward this project and to determine how great a disparity of opinion existed in the meanings of the commonly used terms. Letters were sent to fifty selected men, together with requests to define a number of terms appearing regularly in the current literature. Approximately 80% responded and sufficient information was obtained to ascertain that the need was serious. The following are samples of definitions given for some of the terms; each number represents a different author.

VISUAL ACUITY

1. The identification and recognition of form.
2. More commonly refers to the threshold of separation of two objects having given characteristics and perceived as separate objects.
3. Sharpness of vision in respect to the ability to resolve details.
4. The degree of clearness of vision.
5. The measure of maximum resolution of an eye or of a person.
6. The International Ophthalmological Congress in 1909 adopted an official ophthalmological definition of visual acuity as the reciprocal (expressed in Snellen units) of the resolution threshold when the latter is measured in minutes of arc, and officially held the clinically normal resolution threshold to be one minute of arc, (with clinically normal acuity) therefore 1.0 Snellen Unit. In the 1916 report of the Committee on Standardizing Test Cards for Visual Acuity of the Section on Ophthalmology of the American Medical Association, the black Landolt broken circle was designated the only approved visual acuity target. Organized ophthalmology has never altered, amended, or rescinded any of these designations of visual acuity, adopted a standard of normality, or designated an official target.
7. Pertaining to the quantitive ability of the eyes to see measurable characters.

AMBLYOPIA

1. A state of partial blindness, ordinarily unilateral, in which no lesion can be found in the eye or optic nerve. The amblyopic eye is visually useless, though not devoid of responsibility to light, any more narrow definition of ablyopia must specify the minima of the various visual capacities (in particular, resolution acuity) which make an eye "useful." There is no general agreement upon these minima.
2. Weakness of sight without any apparent change in ocular structure.
3. A partial blindness which is not accompanied by any condition which can be detected as abnormal by inspection.
4. Reduction of visual acuity below standard resolution.
5. Subnormal vision which cannot be improved with optical correction alone.
6. Non-pathological lowering of visual identification. Amblyopia is due to a nerve block set up by the organism in the interests of visual achievement and to relieve a stress between neurological patterns.

PHORIA

1. This is an abbreviation for the word heterophoria: it owes its origin to the ophthalmologist, Stevens. He defined it as a tending of the visual lines away from parallelism, "the determination being made for a point not less than six meters dis-

tance." (p-215 Stevens "Motor Apparatus of the Eyes," F. A. Davis Co., Philadelphia, 1906.) The purists still use the term in the sense that it is a tendency toward deviation of the visual lines away from parallelism when the eyes are fixated upon a target at 6 M, accommodation inactive, the head in the primary position: The tendency of deviation becomes an actual deviation when fusion is suspended. Usage is gradually allowing the use of such phrases as "phoria" at 40 cm. Thus fixation at 6 M and inhibition of accommodation is apparently no longer a necessary part of the definition.

2. The position of the eyeballs in relation to their visual axes.

3. The relative position of the lines of sight of the two eyes in the absence of a stimulus to fusion.

4. There is no excuse for using this "word" which is a disembodied suffix. It is growing toward respectability through ignorant carelessness; and, while usage determines definitions and must be allowed to do so if the language is to evolve, this is one instance in which I side with the medical dictionaries and the purists. No person has or exhibits "phoria"; he either exhibits orthophoria or heterophoria. If the latter, the heterophoria may take the form of exophoria, hyperphoria, cyclophoria, and so on.

5. A description and measurement made in prism values of the relative positions in space of the mentally projected images of the eyes which appear as a result of the suspension of fusion.

6. Absence of parallelism between the visual axes.

RETINAL RIVALRY

1. A phenomenon represented by the failure to perceive a border in the field of view of one eye when it is presented so as to be localized in the same direction in visual space as another border seen by the other eye.

2. A probably mis-named phenomenon in which topographically correspondent portions of the respective monocular visual fields (or their entireties) alternate in consciousness. Two types of rivalry can be sharply distinguished: rivalry of forms and rivalry of colors. Where correspondent portions of the monocular fields contain, simultaneously, similar or slightly dissimilar or greatly unlike forms and similar or slightly dissimilar or greatly unlike colors, rivalry of forms may occur in the absence of rivalry for the colors, or vice versa; or, rivalry of both kinds may occur simultaneously but quite without synchronization. The two kinds of rivalry undoubtedly have distinct physiological bases and separate "loci" in the central visual apparatus.

3. Maintenance of different imagery by the right and left eye in any given spatial area or location.

4. Alternate monocular vision for all or only a part of the binocular field of vision. The mentally perceived image is made up of parts of each monocular image. The percept changing from moment to moment with the part of the perceived image being different.

5. Alternation of sensation as perceived first by one eye then the other when both are perceiving dissimilar characters, depending on fixation and regression. Retinal Rivalry is absent in strabismus.

6. A phenomenon of vision noted chiefly with a stereoscope when the two eyes are viewing different figures or colors and a perceptual alternation occurs.

STEREOPSIS

1. Relating to the perception, in either monocular or binocular vision, of any aspect of a visual object or scene that involves the attribute of "depth" or distance in the toward-and-away direction with respect to the observer.

2. Ability to interpret retinal disparity in terms of depth variable.

3. Technically the ability to appreciate depth in space. In clinical parlance it is generally accepted to be the ability to detect small differences in binocular parallax for different objects in space.

4. The ability to judge distance and power to appreciate the third dimension. According to Burian, it is a fundamental or innate sensation and cannot be taught. What can be taught is the refinement of stereopsis. Once a person has stereopsis he can be trained to enhance that function if it falls below normal level.

5. The perceptual phenomenon seen in a stereoscope and producing the sensation of third dimension. The third dimension refers to the recognition of depth in

natural seeing and does not depend upon binocular vision. A one eyed person will be aware of depth.

It was concluded from this survey that the most practical and realistic approach to a solution would be to attempt unprejudiced definitions of each term which would include as many of the currently existing concepts as possible.

It was originally estimated that this project could be completed in approximately two years, but it was soon apparent that this original estimate was greatly optimistic. It was also realized in the accumulation of terms, the first phase of this project, that the border line between inclusion and exclusion presented a serious problem. In order to make this border line more clearly defined and stable, and at the same time to make the compilation of value, not only to optometry, but to all the visual sciences, the scope was broadened to include all terms relating especially to visual science, in all of its major phases. It was also decided to include a number of elementary statistical terms to assist those without special training in this field.

It was at this point that the compilation had taken on the attributes of a Dictionary of Visual Science. To add to its potential value, self-pronunciations were included for each term. Also a reasonable number of illustrations were included. This enlargement of scope and design meant a great increase in the number of years before the Dictionary could be completed. Now contained in the Dictionary of Visual Science is terminology relating to the following fields: ocular anatomy, ocular physiology, ocular pathology, ocular embryology, ocular neurology, ocular histology, ocular genetics, developmental anatomy of the eye, comparative anatomy of the eye, ocular prosthetics, physiological optics, psychological optics, physical optics, mechanical optics, geometrical optics, practical optometry, theoretical optometry, orthoptics, visual training, dispensing, illumination, contact lenses, subnormal vision aids, occupational vision, and elementary statistics. This list is believed to provide a relatively complete and useful coverage of the visual sciences and should serve to make definitions of the terms in this broad field readily available. It makes the Dictionary of use not only to optometrists, but also to ophthalmologists, oculists, opticians, illumination engineers, visual psychologists, etc.

During the first three years, most of the time was devoted to obtaining listings. To accomplish this, it was necessary to carefully search the literature in all the fields, including text books, journals, syllabi, dictionaries, encyclopedias, research articles, lecture notes, etc. As new publications appeared, they were checked for new terms or new concepts. This, in addition to terms continually brought to our attention by col-

laborators and contributors, has gradually increased the total listings to about 12,500, more than triple the number in any other existing dictionary having its principle emphasis in visual science.

The listings are terms which have special concepts in the visual sciences or are used only in the visual sciences. Definitions of general meaning are not included nor are terms which have only general meaning.

Of necessity a filing system had to be established. Each term has been filed on an index card on which, in addition to the term, has been recorded the sources where definitions or discussions of the term were found. When a term reoccurred in other sources, the additional references were added to its card. At the present time the files contain a comprehensive set of references for each listing, indicating the page and volume of the various sources where the term is to be found. This amounts to one overall index covering all publications examined and, in some cases, this index is more complete and accurate than the index of the publications themselves.

After the listing of terms was essentially completed, consideration was given to defining. It was at this time that Hofstetter, the third author of this report, joined as an editor. Realizing the tremendous amount of work involved and the need for specialists in defining, men who were nationally recognized in their field were solicited to be contributors and collaborators. Cooperation was obtained not only from men in optometry, but also from men in other areas including ophthalmologists, opticians, anatomists, psychologists, physicists, pathologists, illumination engineers, and others. This was considered particularly important, and fortunate, in view of the fact that the three editors all happen to be optometrists, a circumstance attributable entirely to the development of the project from what was originally a purely optometric study. The number of contributors and collaborators has gradually increased until at present fifty-two men representing virtually all the previously mentioned areas in vision, are working on the Dictionary in addition to the three editors. Among these are educators from almost every school of optometry in the United States and Canada. As far as possible, terms are assigned to these men in their special field of study.

The form used in the definitions as well as in the overall pattern of the Dictionary is outlined in a set of rules and instructions provided to each collaborator and contributor. The general pattern of the Merriam-Webster New International Dictionary is being followed, together with such variations as are self-evidently valuable and useful. Etymology and grammatical identifications are not included unless particularly important in denoting the true connotation of a word, or for clarifica-

tion. Every effort is being put forth to make the definitions objective in nature and to represent their actual usage in all concepts. They are listed in the order believed to typify the frequency of usage. An example of a term with more than one meaning is "lag of accommodation," which has been defined as follows:

1. The extent to which the accommodative response is less than the dioptric stimulus to accommodation. The failure to accommodate the full amount demanded for the sharpest imagery of the stimulus object. The phenomenon is quite general and is often referred to as the *lazy lag of accommodation*.
2. In binocular fixation, the failure to accommodate for the full amount of the dioptric stimulus when the convergence response is normal. Hence called the *lag of accommodation behind convergence*.
3. (O.E.P.) By special definition, any index expressed in diopter units obtained by application of a formula using numerical values of several clinical findings. These formulae vary. Most commonly, "that amount of accommodation free of association with convergence as determined by the net of the unfused and fused cross cylinder findings."
4. Rare. The additional lag sometimes induced by dissociating the two eyes.

No encyclopedia type discussions are included. All terms consisting of two or more words are defined under the noun listing. If the term suggests doubt as to which of its several words would be employed in locating it, it is also listed under the modifying word or adjective, where it is cross-filed back to the noun. For example, if one were looking for *Marfan's syndrome*, it would be found in the "S's" under *syndrome*, and also in the "M's" under *Marfan's* where it would be cross-filed to *syndrome, Marfan's*. In this manner all definitions of laws, theories, signs, tests, types of accommodation, etc., are grouped together and are not scattered throughout the context under modifying adjectives.

Terms to be defined are sent to the various men on duplicate 8"x5" cards which contain references for the listing. After being defined and returned, they are edited. Occasionally the definitions are inadequate or incomplete and have to be rewritten or reassigned. The returning of the defined terms in a reasonable length of time has been a particularly great obstacle. Of necessity, men are being relied upon who are occupied with many other pursuits and responsibilities and thus delays are to be expected, however there have been instances in which as few as fourteen terms were out for over a year without being returned. Fortunately this is not the case with most of the collaborators and contributors and at the present time defining has progressed to include approximately 80% of the terms, half of which are edited and are in, or ready for, manuscript. It is estimated that one and a half more years will be needed for completion.

Occasional bulletins are sent to the collaborators and contributors to keep them informed as to current progress, changes in policy, and staff additions.

As yet no commitments have been made for publication. The authors believe however, that this Dictionary will have a relatively good circulation, first, because it will be of particular value to optometric students, (a continuous market for any acceptable publication) and second, because it will be of value to men of the related visual fields, as well as to practicing optometrists, oculists, and ophthalmologists.

The financial hurdles involved just in the preparation and development have been serious. Since grammatical editing, formation of self-pronunciations, and typing of the manuscript was necessary, a qualified person has been employed to do this work. It has also been necessary to employ clerical help to assist in cross-filing, maintenance of duplicate files, etc. The postage alone, representing the mailing of file cards (first class postage) and unending correspondence between editors, collaborators, and contributors, has been a major item. This cost, together with the cost of filing supplies and incidental stenographic assistance has been carried by the Los Angeles College of Optometry, where most of the editing is being done. In 1952, the authors received a grant-in-aid of $200.00 from the Southern California Chapter of the American Academy of Optometry to help defray some of the secretarial expenses. It is estimated that an additional $2,600.00 will be required to meet the expenses incurred by the employment of the manuscript editor and typist alone. To meet this particular cost the American Optometric Foundation and the American Academy of Optometry have been petitioned for financial assistance.*

The editors feel that this book when completed will fill a need in the field of visual science. The time and effort devoted to this task by the many persons involved should represent a significant contribution toward the fulfillment of this need.

*A grant of $1,250.00 has since been received from the American Optometric Foundation.

NOTES ON A NEW GERMAN CORNEAL CONTACT LENS*

Frank Dickinson†
St. Annes-On-Sea, England

During a recent visit to Germany and Austria I spent some ten days with Wilhelm Söhnges, whose practice is in Munich.

*Read before the annual meeting of the American Academy of Optometry, Contact Lens Section, Chicago, Illinois, December 6, 1953. For publication in the July, 1954, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.

†Optometrist, Fellow, American Academy of Optometry.

I was particularly impressed with the success he has achieved with a simple type of corneal contact lens manufactured by Mueller-Welt in Stuttgart. Söhnges' work is confined mainly to three types of lenses, of which two are corneal, one having its inside curve ground to a single radius, the other incorporating dual radii, and somewhat larger in size. The third type is perhaps most familiar to American optometrists. A circular, haptic-fitting lens, it has a small, minimum-clearance corneal sector. Fluidless, it barely clears the apex of the cornea and allows for a broad band of contact towards the limbus.

Söhnges, with whom I had been in close touch prior to World War II and since, had reported quite extraordinary results with corneal lenses and I was anxious to compare notes with him and to exchange ideas. The lens he employs for the great majority of his patients (all, in fact, are initially fitted with it) is under 10 mm. in size and thin enough to be easily flexed. It has no well-defined "bevel," as such, although the finish of the edge, particularly inside, is well tapered. It is ground to a single inside radius, the choice of which is based on the keratometer reading. Söhnges employs a range of approximately two hundred lenses, in order to provide a wide choice of curves and foci. He shares my conviction that success in contact lens fitting depends to a large extent upon the practitioner's ability to place upon each eye a lens which is correct both in fit and focus, so that the patient experiences the greatest degree of comfort combined with the best possible visual acuity in the first lenses he wears.

So precise is the technique he has perfected that in almost every case the first lens becomes the final one. In my own case, it was necessary to try a second lens only for the left eye. The right was correct the first time. That this method saves a very considerable amount of time will be readily appreciated. Indeed, as many as 15 new patients have been fitted in a single day.

On the arrival of a new patient, the routine is described to him in the ground floor salon, from which he is conducted to a refraction cubicle for an estimation of his refractive error and "K" readings. He then proceeds to the fitting room on the first floor, a spacious, well-furnished apartment opening onto a small garden. Armed with the information recorded below, Söhnges or his assistant selects a lens for each eye. After being rinsed in a wetting agent, and again in clear water, the lenses are mounted on the tip of a finger and placed on the eyes. Visual acuity is checked subjectively by the addition of plus and minus trial-case lenses, and if necessary, one or both lenses may be changed. Substitution is, however, rarely found to be necessary. The patient allows the lenses to settle for a few minutes, and then goes out for a

walk around town, reporting back towards the end of the day. In most cases the trial proves successful and he takes his lenses away for a month's wear, at the conclusion of which time he is checked again. He is instructed to wear the lenses for as long a period as they remain comfortable.

When I learned, a few months prior to my visit, that many patients wear their lenses night and day for months at a time, I was, frankly, incredulous. I was able to satisfy myself, however, that this claim is not exaggerated, for I interviewed quite a number of patients and checked the fit and performance of their lenses.

Typical of those who have discarded their spectacles was the case of airman, K. A., of Texas, stationed at the American Air-base of Feldbruck. This patient's refraction is: O.D. —8.50 D.sph. O.S. —8.00 D.sph. ⌣ —0.50 D.cyl. axis 180. When I saw him last August, he had worn his lenses continuously for three months, and when I questioned the wisdom of sleeping in them he expressed surprise, for he was so unconscious of them that he saw no reason to disturb them. Moreover, he experienced no photophobia whatever, not even on bright summer days in a temperature of over 100 degrees. He thought he could stand more light with the lenses on than previously with the naked eye. They were not tinted in any way.

Another patient had achieved a wearing time of 23 weeks, and Söhnges assured me that even this period had been comfortably exceeded by others.

So far as my own lenses are concerned, I cannot yet report such remarkable results. While I have worn them during sleep (a procedure which is both unnecessary and pointless) I obtain greater comfort by removing them at night. In daily use I have worn them on many occasions for more than 15 hours, with a notable absence of after-effects.

Since my return to England I have been working out my own technique with lenses of similar design, and although at this stage I am not ready to report experiences with patients, I can say that my results have confirmed those of my German friend. The type of corneal lens I had been fitting (a pattern evolved from research during my practice in South Africa and, since 1950, in England) is inferior both in wearing time and freedom from after-effects to this new type.

Summing up, I would say that perhaps the greatest contributory factor to the success of the tiny lens is that it makes no attempt to deal with the variations in corneal curvature so frequently encountered beyond the pupilary area. It is small enough to avoid them, for the apical area of the cornea is generally fairly regular in contour. Yet the lens floats freely on the corneal surface. (The Germans call it a "swim-

ming" lens.) It would appear to be least effective for patients with high corneal astigmatism—over five or six diopters—and in aphakic corrections, when its flexibility is impaired by increased center thickness.

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CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organization.

A.O.A. SEATTLE CONGRESS

The 57th Annual Congress of the American Optometric Association was held in Seattle, Washington, June 20-23. The convention headquarters were the Olympic Hotel. Dr. S. L. Brown, Fostoria, Ohio, was elected president of the A.O.A. For the past two years he has served as 1st vice-president of the association. The other officers elected at Seattle are, Dr. Norman B. Hays, Niagara Falls, New York, 1st vice-president; Dr. Rupert E. Flower, Visalia, California, 2nd vice-president; Dr. Joseph M. Babcock, Portsmouth, Ohio, 3rd vice-president; Dr. Lester H. Sugarman, Meriden, Connecticut, 4th vice-president; Dr. James E. Wahl, Anna, Illinois, trustee; Dr. Hoyt S. Purvis, Jonesboro, Arkansas, treasurer, and Dr. Ernest H. Kiekenapp, Minneapolis, Minnesota, secretary.

The delegates voted to hold the 1955 Congress in Milwaukee, Wisconsin, and the 1956 Congress in Denver, Colorado.

A number of reports were presented at the meeting. Among the more significant was the report of Dr. Virgil A. McCleary, Warsaw, Indiana, chairman of the Committee on Social Health Care Trends. This report reviewed the present tendencies towards group private health plans and recommended that the following standards be adopted for optometric participation in these group plans at such time as they include refractive care. (1) Complete independence on the part of the optometrist in professional handling of visual care patients. (2) Unlimited time and facilities for visual analysis, diagnosis, dispensing, progress reports, visual training and subsequent services. (3) Proper remuneration for the participating optometrist. (4) Cooperation of and with physicians. (5) Optometrists who participate in group plans

must be members of their State optometric association, and (6) in these group plans there must be no discount dispensing.

The McCleary report concluded with the additional recommendations that the A.O.A. adopt a position regarding individual participation in all health programs and that the A.O.A. and State optometric Associations study and implement programs for refractive care in private and public health plans on the basis of free choice of doctor.

Dr. E. F. Warren, Washington, D. C., chairman of the Committee on Motorists' Vision, presented a report dealing with the driver's loss of ability to detect contrast in night driving. The report questioned the use of absorption lenses and tinted windshields for night driving.

Dr. I. S. Finkelstein, New York City, Chairman of the Committee on Contact Lenses, pointed out in his report that more and more is the practice growing of opticians and lay persons fitting contact lenses. In some instances, this is supposedly done "under the personal supervision" of the referring doctor; in many other instances, only the most general directions are given and the optician literally prescribes and fits contact lenses. There should be explicit definition of the optician's functions, if any, in this field and a more rigorous enforcement of statutes, once obtained, was urged. The feeling of the committee was that the matter lies largely in the territory of the legal department but that it is an area of critical importance and should be carefully watched. The contact lens field may become an area by means of which optometric practice may be expanded or invaded depending upon the care and vigilance with which we proceed.

Dr. Finkelstein also pointed out that the committee is aware of the fact that the present policy of the American Optometric Association does not permit endorsement or approval by it of any modality or technique. Yet the thought remains that the American Optometric Association might in due course reconsider this policy stand and set up a system of evaluation not only of the modalities but also of the techniques. Sufficient contact lens courses are not presently available and the optometrist who seeks knowledge in this field should not be required to subscribe and pay for a commercially given course.

Dr. Joseph M. Babcock, Portsmouth, Ohio, and William P. MacCracken, Jr., Washington, D. C., in their report of the A.O.A. Department of National Affairs, presented a review which indicated among other things that progress was being made in increasing the number of commissioned optometrists serving as refractionists in the armed services. Their report also covered the present position of other legislative matters of interest to the profession.

During the general business sessions the delegates voted to increase the individual annual dues payable to the A.O.A. from $20 to $30. This action took considerable time. It was once defeated but was passed when reconsidered the following day.

The attendance at the Congress was good. The hotel and the arrangement committee of Washington optometrists did excellent jobs in making the meeting a success.

GOLDBERG SPEAKS BEFORE SAN FRANCISCO-BAY AREA CHAPTER

Dr. Leonard Goldberg, Associate Professor of Pharmacology at the Carolinska Institute of Stockholm, Sweden, and a noted authority on alcohol intoxication and its effects, was guest speaker before the San Francisco Bay Area Chapter, American Academy of Optometry, on the evening of June 10 at the University of California School of Optometry. Dr. Goldberg, a member of the Advisory Committee on Addicting Drugs of the World Health Organization, has been Visiting Professor of Pharmacology at the University of California Medical School during the last semester.

His topic, "The Determination of Fusion Frequency as a Tool for the Study of Drug Action," was concerned with the demonstration of the physiological effects of alcohol and barbiturates on the central nervous system by repeated determinations of critical fusion frequency of flicker after administration of the drug. Dr. Goldberg's method, more sensitive than usual CFF determinations, is actually a determination of critical fusion intensity, for he uses a constant flicker rate and varies the intensity of the flickering light. With this method he has demonstrated interesting differences in the behavior of heavy, moderate, and light drinkers, as well as difference in the effect of alcohol on these individuals. He has also shown for the first time that barbiturates, normally CNS depressants, have a physiologically stimulating action on barbiturate addicts.

THE BULLETIN-WOMAN'S AUXILIARY, A.O.A.

We have just been wondering how many optometrists ever read THE BULLETIN-WOMAN'S AUXILIARY—A.O.A. This nicely done quarterly goes to the wives of optometrists who belong to the Auxiliary. It reviews the current programs and offers suggestions for the future. The writer has known that they issued a publication, but the staff in the Journal office had not seen a copy until editor Koch brought one back from Seattle. If your wife is a member she should get THE BULLETIN. When she finishes reading it—may I suggest that you look it over. In fact, if you read it from cover to cover you will find that these auxiliary

members are doing great things for optometry, and that Ann L. Hoffert, Grand Rapids, Michigan, is doing an outstanding job in editing this 36-page publication.

NEWS BRIEFS

Northern Illinois College of Optometry reports many requests both received and filled by its Speakers Bureau. A number of their faculty people are available for lectures before optometric groups. Program chairman should write the school when in need of speakers. . . . The 11th annual San Jose Visual Training Workshop will be held at the Civic Auditorium, San Jose, California, August 21-22, 1954. Among the speakers will be Dr. Fred W. Suter, Philadelphia; Dr. Merton C. Flom, Berkeley; Dr. L. C. Emery, Pasadena, and Dr. Georg: Crow, Los Angeles. . . . Eighty members of the Association of Independent Optical Wholesalers Association no longer stock toric lens blanks. These laboratories now only carry corrective curve lens blanks. It looks as if toric lenses are on the way out. . . . Mr. H. Freeman, 493 Roman Road, London, E.3, England, will be in America in October. Mr. Freeman is a noted British optometrist, writer, lecturer and instrument designer. He will be available for a few speaking engagements east of the Mississippi during a three-week period. Optometric organizations wishing to secure him as a speaker should write him (air-mail) at once. . . . The Class of 1954 College of Optometry, Pacific University, presented the College with a slit-lamp as a graduation gift. . . . Several members of the Academy are planning to be abroad during the time the International Optical Congress is held in Ireland next year. Among those are Dr. Meredith W. Morgan, Jr., Berkeley, and Dr. Henry W. Hofstetter, Bloomington, Indiana. . . . The Optical Fair was a huge success. According to Mr. Charles F. Oddy, Secretary of the Optical Manufacturers Association, 1,289 optometrists registered at the Fair in Chicago. . . . The A.O.A. is now distributing its 1954 Back to School kit to State Association public relations committees. . . . On June 24, Dr. J. I. Pascal, New York City, lectured to the resident staff of the Chicago Eye, Ear, Nose & Throat College Hospital on strabismus.

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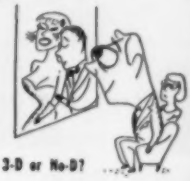

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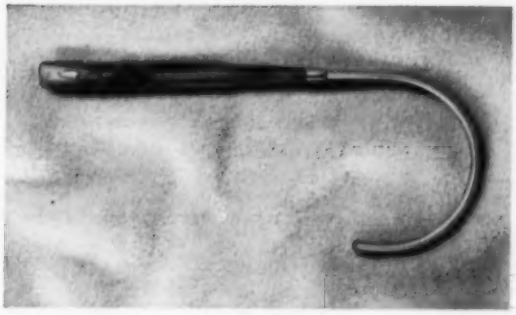

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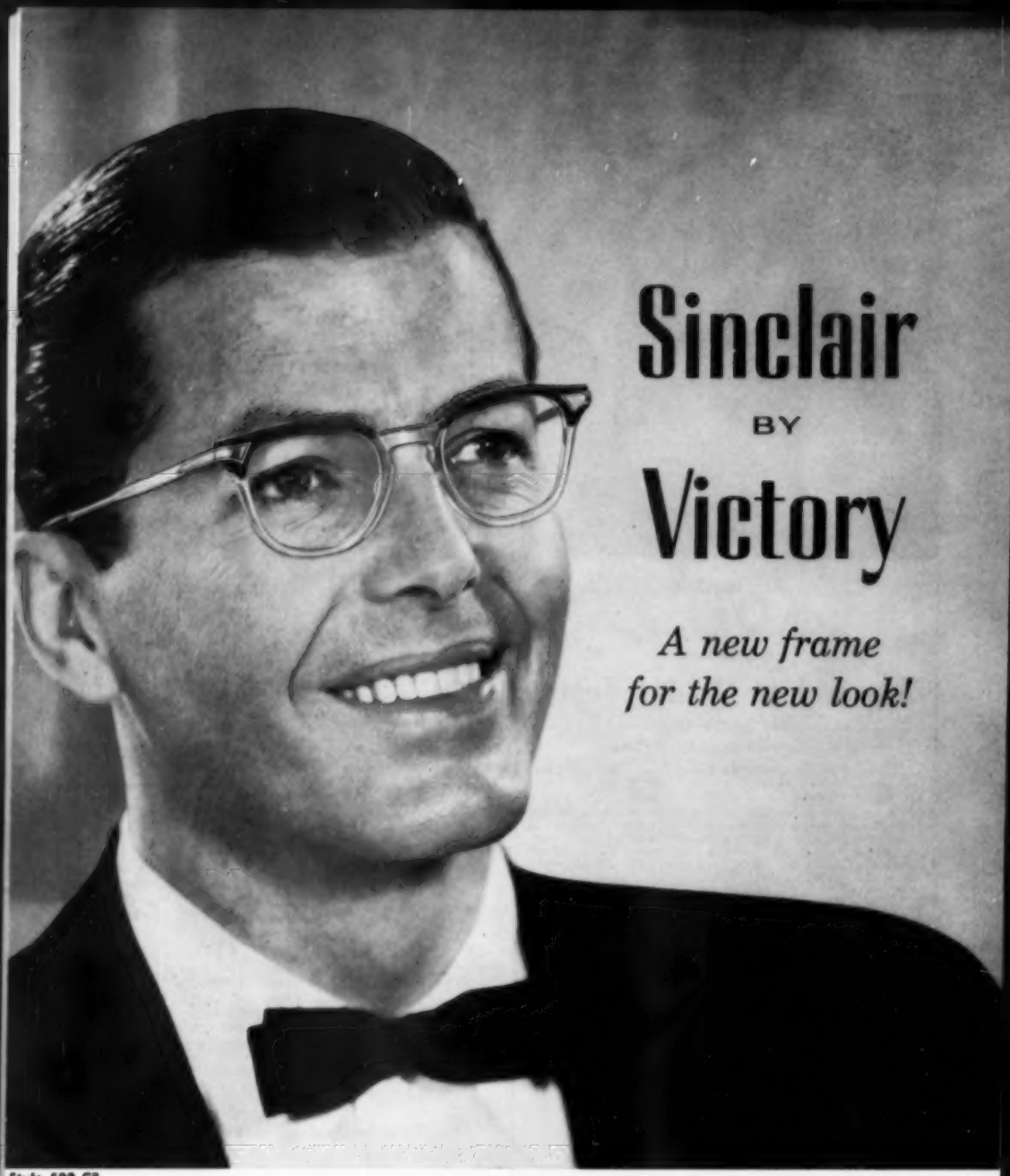

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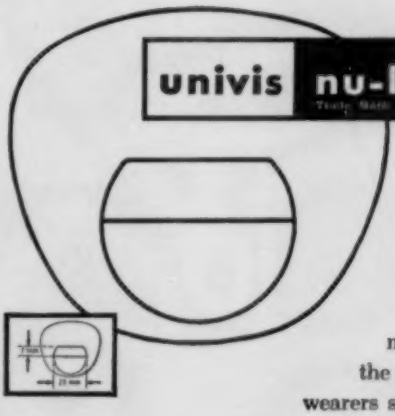

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